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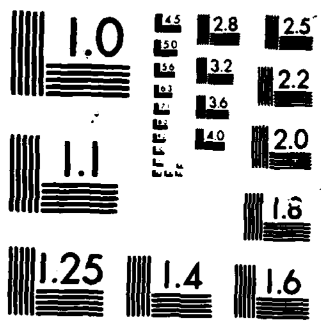

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

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InP:Fe AND GaAs:Cr PICOSECOND
PHOTOCONDUCTIVE RADIATION DETECTORS

by

Phillip J. Keipper

December 1985

Thesis Advisor: F.R. Buskirk

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InP:Fe and GaAs:Cr Picosecond Photoconductive Radiation Detectors

by

Phillip J. Keipper
Lieutenant, United States Navy
B.S., Ohio State University, 1975

Submitted in partial fulfillment of the
requirements for the degree of

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December 1985

Author: Phillip J. Keipper
Phillip J. Keipper

Approved by: Fred R. Buskirk
F.R. Buskirk, Thesis Advisor

John R. Neighbours
J.R. Neighbours, Second Reader

G.E. Schacher
G.E. Schacher, Chairman,
Department of Physics

J.N. Dyer
J.N. Dyer,
Dean of Science and Engineering

ABSTRACT

The dark current, impulse and square-pulse response measurements of photoconductive devices fabricated from two different types of materials, Gallium Arsenide with Chromium dopant (GaAs:Cr) and Indium Phosphide with Iron dopant (InP:Fe) are reported. These devices have been subjected to irradiation from the Naval Postgraduate School S-band Electron Linear Accelerator (LINAC) with an energy of 100 MeV at room temperature. Fluence ranged between 10^{13} and 10^{16} electrons/cm^2. Dark current decreases with increasing fluence for the GaAs:Cr devices whereas InP:Fe shows an increase in the dark current. Both types of materials exhibit extremely fast impulse response after the irradiation. Electron mobility, drift velocity and response speed decrease with increasing fluence. Response speeds < 100-ps are achieved by fast carrier relaxation in the semiconductor due to the introduction of trapping and recombination centers resulting from the irradiation damage. The GaAs:Cr, unlike the InP:Fe, more closely follows the longer square-pulse exhibiting no nonlinearity. All results are consistent with previously investigated neutron irradiated devices.

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I. INTRODUCTION

There has been recent interest in the development of bulk-semiconductor photoconductors with picosecond carrier relaxation time to be used as radiation detectors. Data on the response of semiconductor devices to radiation damage is required for design and development of their use in a radiation environment. These environments include space applications, accelerators, nuclear reactors and nuclear explosions, each of which involve specific irradiating particles. Compact radiation detectors with a high degree of sensitivity to photons, x-rays, soft x-rays, gamma rays, electrons, protons and neutrons are being developed by the Los Alamos National Laboratory Electronics Division. The current response of these devices is proportional to the incident-radiation intensity [Ref. 1].

Particles passing through devices deposit part of their energy into ionization and the remainder into displacement. The interaction with matter depends on properties of both the particle (mass, charge, kinetic energy) and the target (mass, charge, density). Bulk device characteristics are degraded by displacement damage which can decrease carrier mobility, carrier concentration and carrier recombination lifetime.

In the development of these bulk-semiconductor radiation detectors, irradiating particles are being utilized to

damage the device thereby creating trapping and recombination centers. The desired characteristic, specifically, a decrease in carrier relaxation time resulting in response time < 100-ps is obtained while maintaining the sensitivity of the device. In particular, this development entails the use of neutrons with a thermal neutron flux of 9.0×10^{13} (neutrons/cm^2-sec) for periods ranging from 2000-4000 seconds. Neutron transmutation doping in the bulk-semiconductor device is impeded by the filtration of low-energy neutrons [Ref. 1]. This source is provided by the OMEGA WEST REACTOR located at the Los Alamos National Laboratory.

In this thesis, discussion is presented on the radiation effects of high energy electrons on two different types of materials. Before irradiation, measurements of dark current, impulse response (source response shorter than detector carrier relaxation time) and square-pulse response (source response longer than detector carrier relaxation time) were made. The same measurements were made after the irradiation to determine changes in carrier relaxation time giving an indication of the resulting damage. These measurements were carried out utilizing the processes of photoconductivity.

The purpose of the experiment reported here is to determine the effect of 100 MeV electron irradiation on these bulk-semiconductor radiation detectors and the degree to which the displacement effects can be compared with those

of neutron irradiated devices. It is desirable to obtain similar results with the charged particle source (100 MeV electrons) as has been demonstrated with the neutron source.

II. THEORY

A. IRRADIATION

1. Interaction of Electrons with Matter

Electrons incident on a semiconductor interact with the atoms primarily through the process of Coulomb scattering. The electron path may be deflected through large angles and ranges may vary widely even for electrons of the same energy. The electron energy loss per collision may be very high.

At an energy of 100 MeV, the electrons lose energy partly due to ionization of the atoms and partly due to Bremsstrahlung (radiation loss). Stopping power is defined as the amount of energy lost by a particle per unit length of path through the stopping material. For electrons, the total stopping power is divided into two components: 1) collision stopping power--the average energy loss per unit pathlength due to inelastic Coulomb collisions with bound atomic electrons of the medium resulting in ionization and excitation, and 2) radiative stopping power--the average energy loss per unit pathlength due to the emission of bremsstrahlung in the electric field of the atomic nucleus and of the atomic electrons [Ref. 2]. As the electron traverses its path, energy going into ionization and excitation is absorbed by the target relatively close to the path. Energy lost through bremsstrahlung travels farther from the path before being absorbed.

a. Electron Mass Collision Stopping Power

The electron mass collision stopping power is calculated according to Bethe's stopping power theory using the formulation of Rohrlich and Carlson [Ref. 3]

$$\frac{1}{\rho}\left[\frac{\partial E}{\partial X}\right]_{collision} = \frac{2\pi N_a r_e^2 mc^2 Z}{\beta^2 A}\left\{\ln\left(\frac{T}{I}\right)^2 + \ln\left(1+\frac{\tau}{2}\right) + F^-(\tau) - \delta\right\} \tag{1}$$

where:

$$F^-(\tau) = (1-\beta^2)\left[1 + \frac{\tau^2}{8} - [2\tau+1]\ln 2\right]$$

The collision stopping power of a compound can be approximated by the weighted sum of stopping powers of the atomic constituents of the compound. In formula 1, the following replacements are applicable.

$$Z/A \text{ by } \langle Z/A\rangle = \sum_j w_j(Z_j/A_j)$$

$$\ln I \text{ by } \ln I = \left[\sum_j w_j(Z_j/A_j)\ln I_j\right]/\langle Z/A\rangle \tag{2}$$

$$\delta \text{ by } \delta = \left[\sum_j w_j(Z_j/A_j)\delta_j\right]/\langle Z/A\rangle$$

where:

1) w_j is the fraction by weight of the j'th atomic constituent

2) Z_j, A_j, I_j and δ_j pertain to the j'th atomic constituent

Properties of the medium are:

Z = atomic number

A = atomic weight

ρ = density (gm/cm^3)

I = mean excitation energy (eV)

δ = density effect correction

Properties of the electron are:

τ = T/mc^2 - kinetic energy in units of rest mass

β = $v/c \cong 1$

Other parameters are:

$$2\pi N_a r_e^2 mc^2 = .153536\left(\frac{\text{MeV cm}^2}{\text{mole}}\right)$$

Listed under the properties of the medium are the mean excitation energy and the density effect correction. The mean excitation energy is the logarithmic average of the excitation energies of the medium weighted by the corresponding oscillation strengths. One assumption used in determining the mean excitation energy is the use of the I-values of the elemental substances for the I-values of the atomic constituents of the compound. This neglects the molecular binding energies. The density effect correction takes into account the polarization of the medium which screens the electric field acting on the relativistic particle. The effect is a reduction of collision stopping power. [Ref. 2]

b. Electron Mass Radiative Stopping Power

The electron mass radiative stopping power can be expressed using the following formula [Ref. 2].

$$\frac{1}{\rho}\left[\frac{\partial E}{\partial X}\right]_{radiative} = \frac{N_a \alpha r_e^2 E Z^2}{A} \phi^n(\tau)_{rad}\left[1 + \frac{1}{Z}\frac{\phi^e(\tau)_{rad}}{\phi^n(\tau)_{rad}}\right] \quad (3)$$

Properties of the medium (compound) are:

$$A = w_j A1 + w_j A2$$

$$Z = w_j Z1 + w_j Z2$$

where:

1) w_j is the fraction by weight of the j'th atomic constituent

2) A1 = atomic weight of element 1

3) A2 = atomic weight of element 2

Properties of the electron are:

$$E = T + mc^2 = 100.511 \text{ MeV}$$

Other parameters are:

$\phi^e(\tau)_{rad}$ and $\phi^n(\tau)_{rad}$ are dimensionless, scaled, radiative energy loss cross sections

$N_a = 6.022045 \times 10^{23}$/mole

$r_e^2 = 7.940775 \times 10^{-26}$ cm^2

$\alpha = Z/137$

Implicit in the formulation of the electron mass radiative stopping power is electron-nucleus bremsstrahlung (emission of a photon due to the interaction of the electron with the screened Coulomb field of the atomic nucleus) and the electron-electron bremsstrahlung (Coulomb interaction with one of the atomic electrons). The ratio of the scaled, radiative energy-loss cross sections ($\phi^{e}(\tau)_{rad}/\phi^{n}(\tau)_{rad}$) is assumed to be one and values for ($\phi^{n}(\tau)_{rad}$) are approximated from least-squares curves fitted from theoretical points based on Davies, Bethe and Maximon (1954) and Olsen (1955). [Ref. 2]

c. Energy Deposition--Dose Measurements

The range of the electron is defined as the average path length the electron travels until it is stopped by the medium as a result of energy loss. The electrons are assumed to lose energy continuously. If the range is divided by the density of the material, the distance an electron will travel can be determined.

Dose represents the total amount of energy deposited to the medium. It is given in rads (100 ergs/gram) and must be specified for the particular material. The front surface dose (thin sample) is expressed by the following formula [Ref. 4].

$$R = 1.6 \times 10^{-8} \, \Phi \left[\frac{1}{\rho} \left[\frac{\partial E}{\partial X} \right]_{collision} \right]^{RADS} \qquad (4)$$

where:

Φ = electron fluence (electrons/cm^2) is determined from formula (24)

2. Lattice Defects

The type of lattice structure inherent in the study of these devices is the zinc-blende structure. In the diamond lattice structure, each atom lies in the center of a tetrahedron formed by the four nearest neighbors. This structure is restricted to elements. The zinc-blende structure is similar to the diamond lattice with the exception that the two nearest neighbors are occupied by different elements.

There are various types of lattice defects that can occur from 100 MeV electron irradiation. Considering only point defects, the lattice defects are broken up into two main categories which include isolated defects and cluster defects. Within isolated defects, the simplest type of defect assumed is the Frenkel defect. This is an empty lattice site (vacancy) and an atom occupying an interstial position. The Frenkel defect requires an amount of energy given to the atom needed to displace it to the metastable intersitial site. The displacement process depends on the energy of the recoil and its direction with respect to other lattice atoms [Ref. 5]. Other isolated defects include divacancies which result when a high energy recoil atom imparts sufficient energy to displace a secondary atom along with the primary atom. The more complicated cluster defects involve regions containing large numbers of isolated defects.

For binary compounds (zinc-blende structure), the number of possible lattice defects is considerably higher than for elements. The displacement or replacement of atoms may result

in eight types of point defects: two types of vacancies, four types of interstitial atoms (surrounded by similar or dissimilar atoms) and two types of substitution defects [Ref. 6].

In the following sections, the irradiation induced processes of atomic displacements will be considered on a microscopic level. Both single atom and multiple atom displacements are discussed along with the assumptions made in determining the total number of displaced atoms. A complete review of damage theory is found in Seitz and Koehler [Ref. 7].

a. Atomic Displacement Cross Sections

For 100 MeV incident electrons (relativistic), enough energy is transferred to the lattice atoms to knock them from their normal lattice position into an interstitial site. These primary knock-on atoms may in turn depart some of their energy to form secondary displaced atoms. Radiation damage theories concentrate on these few elastic collisions.

In the relativistic range, McKinley and Feshbach [Ref. 8] formulated an expression for lower Z elements using the Rutherford differential cross section.

$$d\sigma_{mf} = R_{mf} \, d\sigma_{ruth} \qquad (5)$$

where

$$R_{mf} = (1-\beta^2)\left[1-\beta^2 \frac{T}{T_m} + \pi\alpha\beta\left(\left(\frac{T}{T_m}\right)^{1/2} - \frac{T}{T_m}\right)\right]$$

The differential cross section of the atom must be integrated over all transferred energies. Additionally, the assumption

is made that recoil energies below the threshold displacement energy (T_d) have a probability of zero for displacing an atom whereas those recoil energies above the threshold displacement energy (T_d) have a probability of one. For thin samples, the energy loss is approximately constant over the sample thickness. The displacement cross section is dominated by small angle scattering at 100 MeV energies and is given by

$$\sigma_{mf} = 2.495 \times 10^{-25} cm^2 \frac{Z^2}{\beta^4 \gamma^2} [(\frac{T_m}{T_d} - 1) - \beta^2 \ln \frac{T_m}{T_d} + \pi\alpha\beta\{2[(\frac{T_m}{T_d})^{1/2} - 1] - \ln \frac{T_m}{T_d}\}] \qquad (6)$$

Parameters are:

T_m = maximum recoil energy = $\frac{2(E+2mc^2)E}{M_2c^2}$ (eV)

E = energy of the incident electron = 100 MeV

m = rest mass of the electron

M = mass of the target atom

T_d = threshold displacement energy (values given in Table 1)

α = Z/137

If the primary atom has sufficient energy, additional displaced atoms are produced forming a displacement cascade. In order to determine the effective cross section for both primary and secondary displacements, $\nu(T)$, the average number of displacements per primary recoil of energy T, must be determined. A number of assumptions are made. [Refs. 5,9,10]

TABLE 1

THRESHOLD DISPLACEMENT ENERGIES [REF. 9]

Substance	GaAs		InP	
Displaced Atom	Ga	As	In	P
Threshold Electron Energy E_b (keV)	228	273	270	110
Threshold Displacement Energy T_d (eV)	8.8	10.1	6.6	8.8
Self-Diffusion Energy (eV)	5.6	10.2	3.85	5.65

1. A step junction threshold is assumed.
2. Atom-atom collisions are treated as hard-sphere elastic interactions.
3. The ordered arrangement of atoms in the lattice structure is not considered.
4. Damage is considered homogeneous.
5. Annealing is not considered.
6. Glancing collisions are not considered even though energy loss may be incurred.
7. The number of replacements per primary are not considered. The moving atom will replace the struck atom if the latter receives energies greater than T_d and the former retains energy less than T_d.
8. Lattice atoms are considered at rest.
9. Long range effects from other atoms are not considered.
10. There is no account for ionization losses.

Kinchin and Pease [Ref. 11] consider the threshold energy by postulating that both the striking and struck atoms

require an energy T_d or greater after the collision. This accounts for replacements but does not account for the energy loss of the primary atom in climbing out of its potential well. Figure 1 displays the assumptions made by Kinchin and Pease in calculating the average number of displacements. The Snyder and Neufeld model [Ref. 12] does not account for replacement but does account for the potential binding energy. In this model, the secondary atom loses energy T_d before making subsequent displacements. The average number of displacements per primary recoil of energy T_d is given by

$$\begin{aligned} \nu(T) &= 1 \qquad T_d \le T \le 2T_d \\ &= \frac{BT}{T_d} \qquad 2T_d < T < T_i \end{aligned} \tag{7}$$

Parameters are:

T = average energy transferred = $T_d\,(\ln T_m/T_d - 1 + -\lambda)$

T_i = Ionization Energy = $ME_G/8m_e$

B = .5 (Kinchin and Pease); .56 (Snyder and Neufeld)

For compounds, the ratio of the atomic masses influences the transferred energy. The maximum energy transferred is λ times the energy of the striking atom where [Ref. 9]:

$$\lambda = \frac{4M_1M_2}{(M_1 + M_2)^2} \tag{8}$$

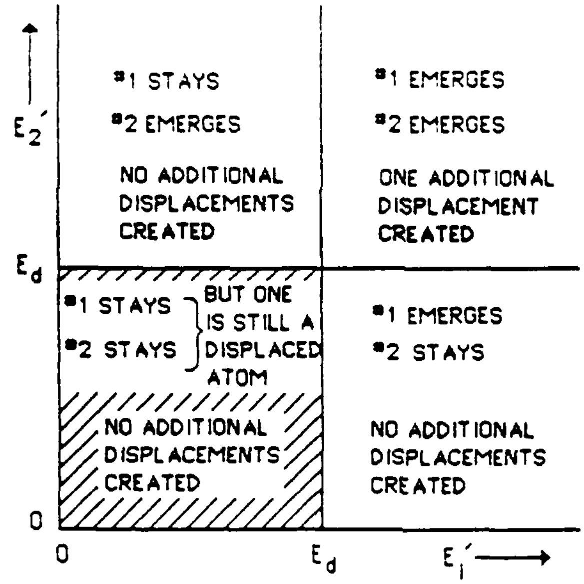


Figure 1. Kinchin and Pease assumptions for calculating the average number of displacements [Ref. 10]

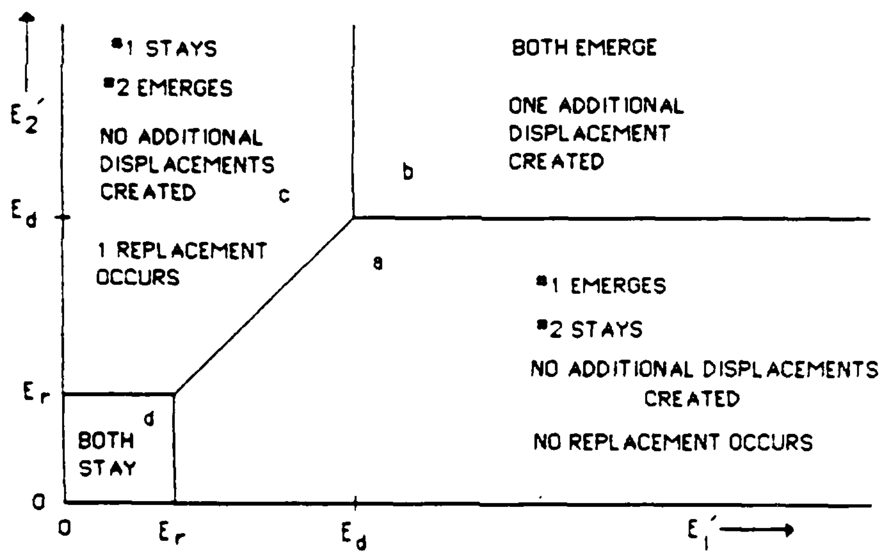


Figure 2. Kinchin and Pease assumptions for calculating the average number of replacements [Ref. 10]

The Kinchin and Pease model holds for compounds provided there is equal probability of collision for the secondary atoms. Replacement collisions involving unlike atoms are called misplacements and account for a substantial portion of the damage.

The effective cross section for primary and secondary displaced atoms in compounds is determined by multiplying (6), (7) and (8).

$$\sigma_d = \sigma_{mf} \, \nu(T) \, \lambda \tag{9}$$

b. Number of Displaced Atoms

In the previous section, the total cross section for both primary and secondary displacements was determined. From this, the density of Frenkel defects (for thin samples) produced per cm^3 can be determined given the incident electron energy and fluence. [Ref. 13]

$$N_F = \phi_e \, \sigma_d \, N_o \tag{10}$$

Parameters are:

N_F = number of Frenkel defects per cm^3

σ_d = total displacement cross section

ϕ_e = electron fluence

N_o = number of lattice atoms per cm^3 $= \dfrac{\rho \, N_a \, \# \text{atoms}}{A}$

where:

ρ = density (gm/cm^3)

N_a = Avogadro's number = 6.02×10^{23} (atoms/mole)

A = atomic number of the target molecule

The number of Frenkel defects determined experimentally from various sources is always less than the number predicted by theory. This is a function of the assumptions made in formulating the various models.

c. Replacement Collisions

Replacement collisions occur when there is an exchange of roles between the primary and secondary knock-on atoms. For binary compounds, the exchange can be between similar or dissimilar atoms and will occur when the moving atom imparts sufficient energy to the stationary atom to cause displacement but does not retain sufficient energy to escape the potential well of the vacancy, thereby replacing the displaced atom.

Dienes and Vineyard [Ref. 10] have determined the number of replacements per primary atom of energy T to be

$$\mu(T) = \frac{T}{2T_d}[1.614 \ln(\frac{T_d}{T_r}) + 1] \quad T \geq 2T_d \qquad (11)$$

The replacement thresnold T_r has not been determined experimentally, however, Kinchin and Pease have suggested a ratio of $T_d/T_r = 10$. A summary of the Kinchin and Pease assumptions for

determining the average number of replacements is found in Figure 2.

d. Radiation Effects

The macroscopic electrical properties of semiconductors are affected by the microscopic defects resulting from electron irradiation. The specific type of damage is a function of many different variables including temperature during irradiation, energy spectra, impurity and dopant concentrations, rate and history of the irradiation and minority carrier injection ratio. The introduction of energy levels within the forbidden gap due to point defects will be considered.

Point defects primarily affect the electrical properties by their ability to either produce or remove charge carriers, change carrier mobility or both. Several models have been proposed to explain the behavior of Frenkel pairs in semiconductors, especially in silicon and germanium. James and Lark-Horovitz [Ref. 14] have suggested that interstials act as donors below the conduction band with two donor levels assigned whereas empty acceptor states above the valence band are produced by vacancies. The relative location in the forbidden gap will ultimately determine the net effect of these localized states with electrons redistributing themselves to fill the low energy states. Blount [Ref. 15] based his arguments on atomic and molecular orbitals stating that each defect can act as either donor or acceptor, depending on the position of the Fermi level. As the concentration of irradiation defects increase to a level

which is considerably greater than the concentration of impurities, the Fermi level approaches saturation and is determined by the distribution of defect levels in the forbidden gap. Table 2 lists energy levels that have been experimentally determined for InP and GaAs [Refs. 9,16].

TABLE 2

InP AND GaAs ENERGY LEVELS

Band Gap E_G, opt (300°K)		Forbidden Gap Energy Levels in eV at 300°K with Electron or Gamma Irradiation			
		Below Conduction Band		Above Valence Band	
InP	GaAs	InP	GaAs	InP	GaAs
1.260	1.430	0.285	0.13		0.35
			0.38		
			0.52		

The effect on the processes of photoconductivity due to the introduction of energy levels in the forbidden gap during electron irradiation will be discussed in the following sections.

B. PHOTOCONDUCTORS

1. Photoconductivity

A photoconductor consists of a bulk-semiconductor material with ohmic contacts (Figure 3). The electrical conductivity is equal to the product of the number of charge carriers, their charge and their mobility. The steady-state

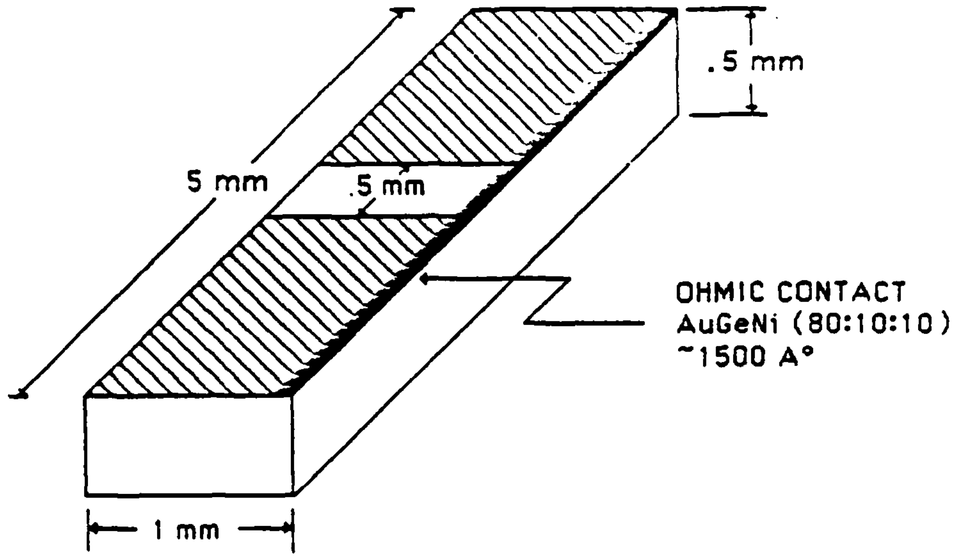


Figure 3. Picosecond Photoconductive Radiation Detector

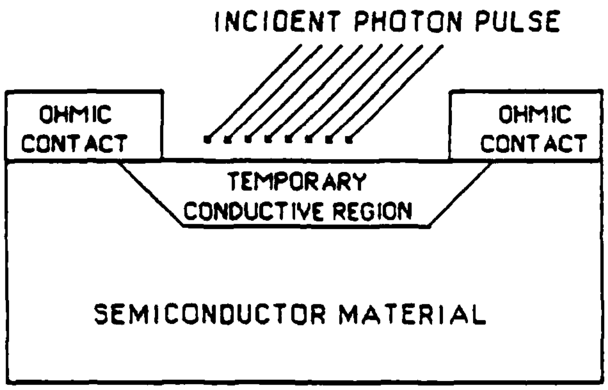


Figure 4. Method of Operation. The region between the ohmic contacts is illuminated with the photon source. The photons are absorbed creating free charged carriers (electrons and holes) which produce a temporary conductive path between the contacts. The full-width at half maximum (FWHM) impulse response measurement is a measure of the photoconductor response speed. It is a function of the carrier recombination lifetime in the active region. [Ref. 22]

contribution to the electrical conductivity resulting from photon irradiation is defined as the photoconductivity. In nonhomogenous semiconductors, the ideal of an "effective mobility" is used to describe low conductivity barriers which limit the flow of current through the material [Ref. 6]. Steady-state photoconductivity is expressed as

$$\Delta\sigma = q(n\Delta\mu_n^* + p\Delta\mu_p^*) \quad (12)$$

When excited by an external photon source, charged carriers are generated by either band-to-band transitions (intrinsic) or by transitions involving forbidden gap energy levels (extrinsic). It is the extrinsic transitions which will be of interest in this experiment. Photoconductivity takes place by the absorption of photons of energy equal to or greater than the energy separation between the forbidden gap levels and the conductance or valence band levels. The conductance of these devices is proportional to the intensity of the incident photon source and takes place via a temporary conductive region between the ohmic contacts (Figure 4) resulting from the creation of free electrons and holes. This nearly intrinsic region consists of a high concentration of forbidden gap energy levels acting as recombination centers. For transient photoconductivity, the picosecond response time depends on the carrier relaxation time and not on the spacing between contacts. This allows for a large bias across the device thereby increasing

the sensitivity. Quasi-neutrality and ideal ohmic contacts are assumed. [Ref. 17]

Desirable material properties for radiation detector applications include short carrier recombination lifetime, high carrier drift velocity, high resistivity (low dark current) and high carrier mobility [Ref. 18]. The efficiency of the photoconductor is measured in terms of its photoconductive gain, response time and sensitivity. It has been concluded that the transient recombination is a bulk controlled process for InP:Fe [Ref. 18].

2. Recombination Centers and Carrier Relaxation Time

The time that a charged carrier is available to contribute to the conductivity is defined as the free lifetime. For excited electrons, it is the time spent in the conduction band. For excited holes, it is the time spent in the valence band. Both minority and majority carriers contribute. The free lifetime is limited by three different processes: 1) extraction of the carriers from the photoconductor without replacement as a result of a voltage bias, 2) absorption into a trapping center, 3) recombination with a carrier of opposite sign at a recombination center. The distinction between a trapping center and a recombination center is statistical in nature and is delineated as follows: in a trapping center, a captured carrier has a greater probability of thermal re-excition to a free state whereas a recombination center provides the captured carrier with a greater probability of recombining with a carrier of the opposite

sign. A demarcation line represents that level which gives equal probability for either event to occur. Figure 5 displays the relative position between the Fermi level and the demarcation level. Area I represents those levels (electron traps) in which the occupation depends on the thermal equilibrium between the conduction band and the level. The occupation of the levels in Area IV (hole traps) depends on the thermal equilibrium between the valence band and the level. Due to the high density of occupied levels in Area II, recombination is taking place even though the conduction band is still in thermal equilibrium with these levels. [Ref. 19]

Recombination takes place via bound states in the forbidden gap. These bound states are comprised of impurities, crystal defects, vacant lattice sites and interstial atoms [Ref. 20]. Before irradiation, the energy levels in the forbidden gap are due to the chemical doping of the sample and determine the number of charge carriers. Irradiation produces defects resulting from atomic displacements and introduces energy levels into the forbidden gap of semiconductors. These energy levels are often deeper in the gap than those dominating conductivity and serve as recombination centers for electrons and holes. The process of recombination at the local centers is influenced by the carrier population of the centers. The capture of the minority carrier is generally the limiting step in the recombination process. There are four processes through which free carriers interact at these recombination centers: 1) electron

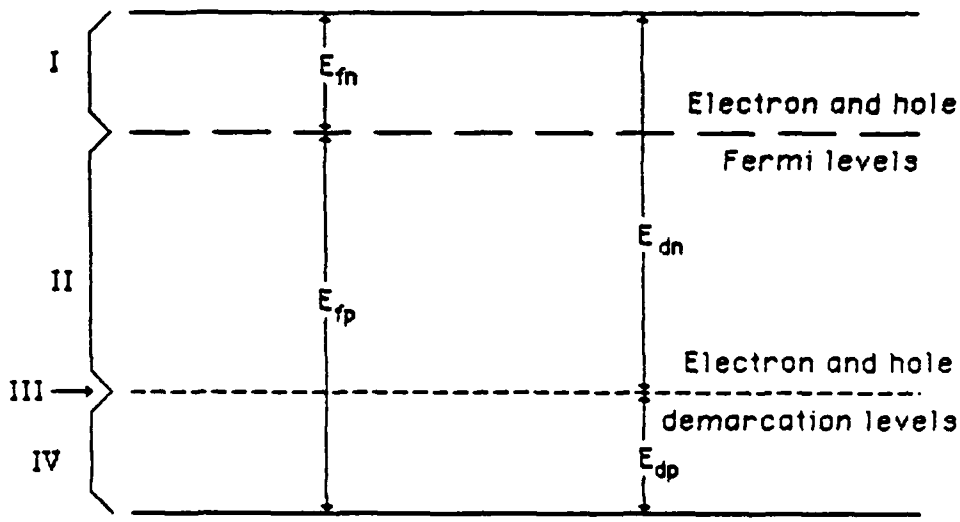


Figure 5. Semiconductor Fermi levels and demarcation levels [Ref. 19]

capture--the process in which an electron falls from the conduction band into an neutral localized state, 2) electron emission--the emission of an electron from the negatively charged localized state into the conduction band, 3) hole capture--the falling of an electron from the negatively charged localized state into the valence band, 4) hole emission--the excitation of an electron from the valence band into the neutral localized state. These processes are illustrated in Figure 6. The net rate of recombination is defined by the following equation:

$$U = \frac{N_t v_{th} \sigma_n \sigma_p (pn - n_i^2)}{\sigma_p \left[p + n_i \exp\left(\frac{E_i - E_t}{kT}\right) \right] + \sigma_n \left[n + n_i \exp\left(\frac{E_t - E_i}{kT}\right) \right]}$$

$$= \frac{(pn - n_i^2)}{\tau_{no} \left[p + n_i \exp\left(\frac{E_i - E_t}{kT}\right) \right] + \tau_{po} \left[n + n_i \exp\left(\frac{E_t - E_i}{kT}\right) \right]} \qquad (13)$$

where σ_n and σ_p are the electron and hole capture cross sections, v_{th} is the carrier thermal velocity, N_t is the recombination center density, E_t is the recombination energy level and E_i is the intrinsic Fermi level.

Figure 7 displays the relative position of the Fermi level (E_f), the recombination center (E_t), center of the band gap (E_i) and the demarcation level (E_d). The minority lifetime of a free carrier varies depending on the relative positions of these levels. All six cases assume the density of the recombination centers to be greater than the density of the

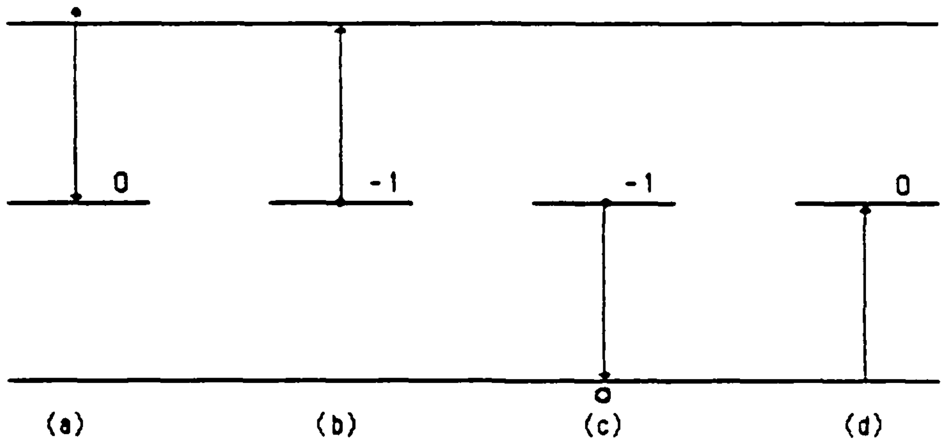


Figure 6. Recombination processes [Ref. 19]

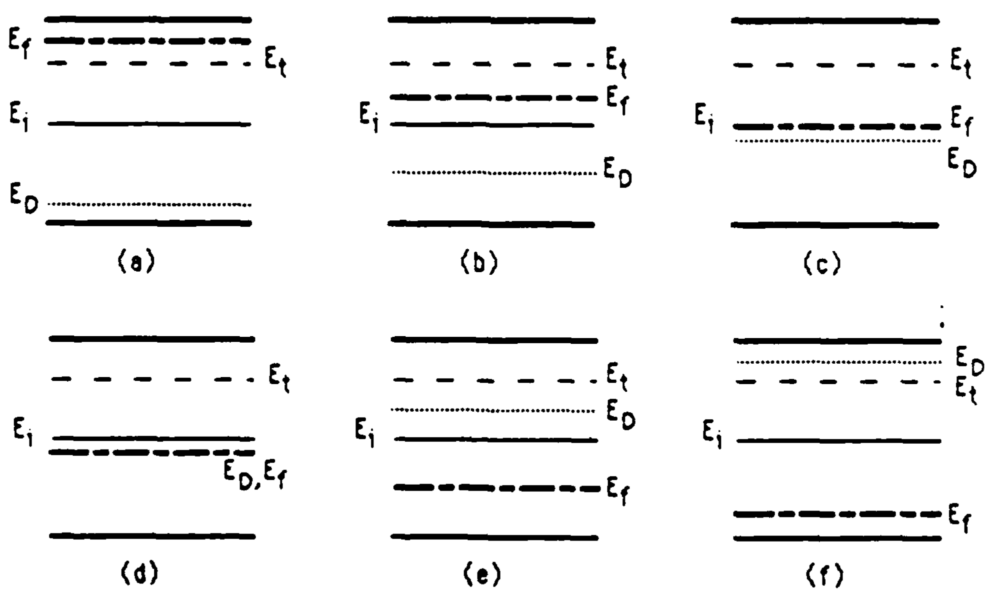


Figure 7. Relative positions between Fermi level, recombination center level, center of band gap and demarcation level in a semiconductor [Ref. 19]

free carriers. Additionally, the recombination processes apply to all levels lying between the Fermi level and the demarcation level, with an exponential decrease in the contribution to centers outside the bounds of these levels. The Fermi level and demarcation level move in opposite directions but at an equal rate.

The carrier relaxation time is due to the trapping and recombination of the free carriers in the conductive region. A mechanism for electron and hole capture in the InP:Fe samples suggests that an acceptor state .61 eV below the conduction band results from the Fe dopant. This acceptor state can exist in either of two charged configurations. Electrons are captured via the neutral state. The negatively charged state acts as a recombination center with the capture of holes. The relaxation time is characterized by the following equations. [Ref. 1]

$$\partial n(t)/\partial t = f(t) - r_{CT} \tag{14}$$

$$\partial p(t)/\partial t = f(t) - r_{TV} \tag{15}$$

$$\partial n_{T-}(t)/\partial t = r_{CT} - r_{TV} \tag{16}$$

$$r_{CT} \equiv v_e \sigma_e n_{TO}(t) n(t) \tag{17}$$

$$r_{TV} \equiv v_h \sigma_h n_{T-}(t) p(t) \tag{18}$$

where n(t) and p(t) represent the electron and hole concentrations, $n_{T^-}(t)$ and $n_{T_o}(t)$ are the concentration of charged and neutral acceptor states, f(t) is the generation rate, r_{CT} is the capture rate of electrons by the neutral acceptor states, r_{TV} is the capture rate of free holes by the negatively charged acceptor state, v_e and v_h are the thermal velocities of electrons and holes, and σ_e and σ_h are the capture cross section for electrons and holes at the neutral and negatively charged acceptor state.

Transient photoconductivity involves the assignment of two characteristic times to the forbidden gap energy levels to describe the recombination process. The transient time constants for small excess carrier densities in a nondegenerate semiconductor near thermal equilibrium are described by the following formulas. [Ref. 17]

$$\Delta n(t) = A_n \exp(-t/\tau_{RA}) + B_n \exp(-t/\tau_{MR}) \tag{19}$$

and

$$\Delta p(t) = A_p \exp(-t/\tau_{RA}) + B_p \exp(-t/\tau_{MR}) , \tag{20}$$

where the initial conditions determine the coefficients A_n, B_n, A_p and B_p. The equal capture rate for electrons and holes by a recombination center requires a readjustment of charges. The time needed for this readjustment is denoted by τ_{RA} and is identical for both electrons and holes. For the condition

when $N_{TT} << n_i$, τ_{MR} (the main recombination lifetime) does not equal the steady-state lifetime. [Ref. 17]

3. Impulse Response

Impulse response occurs when the source response is shorter than the detector carrier relaxation time. The conductance of the device is the result of photon absorption and increases linearly with the energy of the radiation pulse. This absorption produces free electrons and holes that provides a conductive path between the metallic contacts (as illustrated in Fig. 4). The response time is a property of the material and depends inversely on the uncharged recombination centers. The 100 MeV electron irradiation damages the device in such a way as to create trapping and recombination centers which produce faster response times and increased sensitivity.

Desirable properties for detector application includes a peak current response which is proportional to the light intensity and a response speed which is independent of light intensity [Ref. 21]. The peak current response is indicated by the following formula. [Ref. 22]

$$I = \frac{(1-R_r)\ q\ v_d\ E}{S\ w} \tag{21}$$

Parameters are:

I = observed peak current

q = electronic charge = $(1.6 \cdot 10^{-19}$ C)

v_d = electron drift velocity = $\mu V_{appl}/S$

E = Energy deposited into detector by incident radiation = (580 ± 20% pJ)

S = contact spacing = (.05 cm)

W = Energy to create an electron-hole pair = (5 eV

R_r = Reflectivity = (30 percent)

The assumptions implicit in this formula are an incident radiation pulse which is much shorter than the carrier relaxation time of the device, the impedance of the device is always much greater than that of the 50 ohm load and current resulting from the free holes is ignored because of the much lower drift velocity.

The electron mobility in the radiation detector may be approximated by using the measured peak current.

$$\mu = \frac{I S^2 W}{(1-R_r)\, q V_{appl} E} \tag{22}$$

where:

V_{appl} = applied voltage

4. <u>Square-Pulse Response</u>

Square-pulse response occurs when the source response is longer than the detector carrier relaxation time. It is a measure of the relative change in the electron and hole populations. The transient response for InP:Fe is controlled by the trap-assisted recombination of electrons and holes [Ref. 1].

For square-pulses (long radiation pulse), the uncharged acceptor states become negatively charged due to electron trapping. This is a very fast process which leads to saturation

by the negatively charged acceptor states. At the same time, hole trapping by the negatively charged acceptor states is occurring but at a slower rate due to a substantially lower hole mobility. At a certain point, the hole population exceeds the electron population and thus makes the dominant contribution to the current. When both electron and hole trapping rates equal the hole-electron generation rate, steady-state is achieved. [Ref. 1] This is entirely dependent on the intensity of the incident square-pulse. The peak current response is measured by the following formula.

$$I = \frac{(1-R_r)\, q\, v_d\, p\, \tau}{S\, W} \tag{23}$$

Parameters are:

p = optical power

τ = recombination lifetime

5. Photoconductive Gain

Photoconductive gain is defined as the ratio of the recombination lifetime of the charged carriers to the transit time across the active area between electrodes. The bulk picosecond photoconductor decouples the dependency of the carrier recombination lifetime with the transit time. The response speed is a function of the carrier relaxation time within the active region and is thus independent of electrode spacing and bias. A necessary condition for photoconductive gain to be greater than unity is provided by the injection of electrons

into the device by the metallic contacts. This replenishes those electrons leaving the exit electrode. For each non-reflected incident photon, more than one electron is delivered to the external circuit. Photoconductive gains as high as 5 have been demonstrated in InP:Fe photocnoductors with AuGe and AuSn contacts annealed at 450 C [Ref. 22].

III. EXPERIMENTAL PROCEDURES

A. RADIATION FACILITY

Irradiations were performed using the Electron Linear Accelerator (LINAC) at the U.S. Naval Postgraduate School. The LINAC is a travel-wave accelerator consisting of a disk-loaded circular waveguide thirty feet long divided into three ten-foot sections. A series of three klystron amplifiers are used to feed RF power into each ten-foot section. Electrons are initially produced by an electron gun and are injected into one end of the sections where those in proper phase relation will be accelerated. A magnetic quadrupole doublet located downstream from the deflection magnets serves to focus the beam on the target.

The LINAC operates with an electron beam pulse length of 1.0 micro-second at a repetition rate of 60 pulses per second. Electrons are focused on a target positioned in a target chamber with a vacuum of 10^{-6} Torr maintained by a diffusion pump. In this experiment, electrons leave the accelerator at an energy of 100 MeV and an average electron current of 1 micro-ampere.

Electron fluence is measured by secondary emission monitors (SEM). Two SEM's were used during the experiment. A smaller SEM was placed inside the vacuum chamber in front of the target. A larger SEM was placed outside of the vauum chamber in the beam line after the target. Prior to irradiation of the target, the SEM's were calibrated. The larger SEM was previously calibrated

against a Faraday cup and was determined to have a 6% efficiency [Ref. 23]. The smaller SEM was calibrated against the larger SEM. As the electrons impact the SEM's, secondary electrons charge a capacitor. A voltage integrator measures a voltage developed across the capacitor which is proportional to the charge. The ratio of voltages between SEM's is 2.33 which equates to a 2.6% efficiency for the smaller SEM. The electron fluence is determined by the formula

$$\Phi = \frac{C\,V}{(.026)\,qA} \tag{24}$$

where Φ is the electron fluence in electrons/cm^2, C is the capacitance in Farads, V is the integrated voltage in Volts, q is the charge of an electron, A is the area of the beam in cm^2 and .026 the SEM efficiency correction factor. A more extensive description of the LINAC and its operating parameters may be found in Reference 24.

B. SAMPLE FABRICATION

Devices are fabricated from two different types of materials: Indium Phosphide with Iron dopant (InP:Fe) and Gallium Arsenide with Chromium dopant (GaAs:Cr). The procedure was developed and performed by the Los Alamos National Laboratory (LANL) Group E-11. The single crystal materials are obtained commercially, the InP:Fe from CrystaComm Inc. and the GaAs:Cr from Cambridge Instruments LTD. The InP:Fe samples are claimed by the manufacturer to have a resistivity of 2×10^7 ohm-cm and an electron mobility of 2200 cm^2/V-sec.

The crystal is cut with a diamond saw to a specified size (5 mmL × 1 mmH × .5 mmD). The surface is polished and bromine etched to remove any damage. The samples are then rinsed with methanol and de-ionized water to remove the bromine solution. Positive resist photolithographic liftoff is applied while spinning @ 1000 rpm/5 sec and then baked for 30 minutes at 60°C. The samples are then rinsed with methanol while spinning, baked again and placed in a masked aligner where they are exposed to ultra-violet light for 25 seconds. Metallic contacts are applied to the device by a multi-step vacuum evaporation of Au, Ge, Ni compount (80% 10% 10%). Acetone is used to dissolve the .5 mm masked gap exposing the material. The samples are then annealed at 450°C for 2 min. The sample is supported by a 5 cm × 5 cm alumina substrate with 50 ohm microstrip transmission lines and SMA coaxial connectors. A section of the transmission line is removed and the sample is mounted with conductive silver epoxy which makes electrical contact. During all tests, one end of the sample connection was biased and the opposite end (current-signal measurement) was connected into the sampling oscilloscope (25-ps risetime). The mounted sample is illustrated in Figure 8.

C. MEASUREMENT TECHNIQUES AND INSTRUMENTATION

1. Pre-irradiation

Before irradiation, all samples were evaluated to determine current vs voltage characteristics (dark current), impulse response and square-pulse response measurements. A total of

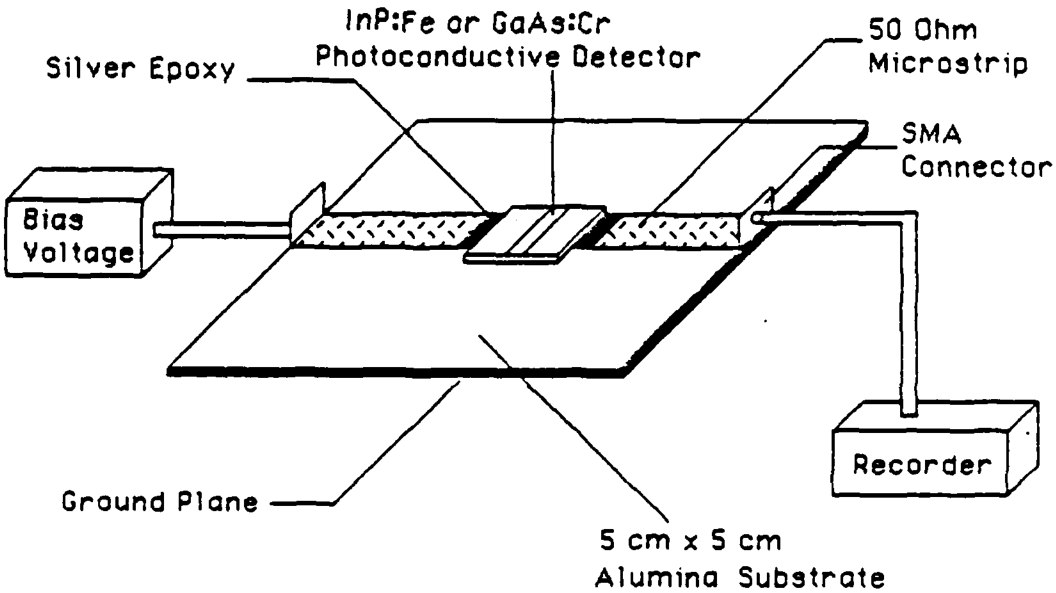


Figure 8. Mounted photoconductive detector in the double-ended configuration

eight InP:Fe and four GaAs:Cr samples were prepared. Ingot numbers are listed in Table 3. All measurements were performed at LANL.

Dark current curves were determine using an Ortec Detector Control Unit (Model 210). The InP:Fe samples were biased up to 500 volts in 100 volt increments. The GaAs:Cr samples were biased up to 125 volts in 25 volt increments. Figures 9 through 13 display the reference plots.

Impulse response measurements were evaluated using the equipment listed in Appendix A. The coaxial, double-ended mounted samples (with separate bias and signal cable connections) were pulsed with the Hamamatsu Picosecond Light Pulser (90-ps FWHM optical pulses) at a frequency of 10 KHz and a wavelength of 820 nm. During the procedure, a bias of 200 volts was maintained on the InP:Fe samples and 100 volts on the GaAs:Cr samples. The signal was evaluated using the Tektronix TDR/Sampler, Processor, Acquisition Unit and Oscilloscope. The determination of amplitude, full-width at half maximum and baseline tail was made and photographs taken. Results are listed in Table 3.

Square-pulse response measurements were evaluated using the equipment listed in Appendix B. The samples were pulsed with the Tektronix PG 501 Pulse Generator which produces an optical source with fast risetime and falltime (150-ps), constant power (3 mW) and continuously-variable-duration optical pulses at a wavelength of 830 nm [Ref. 1]. As in the impulse response measurements, the InP:Fe samples were biased at 200

volts and the GaAs:Cr samples were biased at 100 volts. The signal was processed using the Tektronix 7104 Oscilloscope (with listed supplemental units) and was sent through the Princeton Applied Research Signal Averager before being recorded on the Hewlett Packard 7044A X-Y Recorder. Both photographs of the oscilloscope signal and the final X-Y graphs were used to determine the rise time constants of the square-pulse response. The results are listed in Table 4.

2. Post-Irradiation

After the above characterization was made, the samples were irradiated. Two coaxial, double-ended mounted samples plus a phosphor target plate were mounted on an aluminum ladder and placed in the vauum chamber of the LINAC for irradiation. A vacuum of approximately 10^{-6} Torr was maintained. The samples were connected to coaxial cables to allow for a bias voltage and current measurement (dark current) during the irradiation. The beam was focused on the phosphor target plate and the area was adjusted. A video camera monitored the samples to allow for proper positioning of the beam. The smaller SEM was used along with a 1 micro-F capacitor to measure the integration of the voltage.

The samples were irradiated obtaining fluence in the range of 10^{13} to 10^{16} electrons/cm^2. Formula (24) was used to determine the exact fluence. Dark current measurements were performed just prior to irradiation and immediately after the irradiation. An attempt was made to measure dark current during

the irradiation by placing the beam in standby, however, this was fruitless due to the excitation of the samples.

After the samples have been removed from the vacuum chamber and monitored for residual radiation, they were sent to LANL for post-irradiation measurements. These measurements followed the exact procedure as for the pre-irradiation measurements and the two were compared to determine the effect of the electron bombardment. The results are displayed in Figures 9 through 25 and listed in Tables 3 and 4.

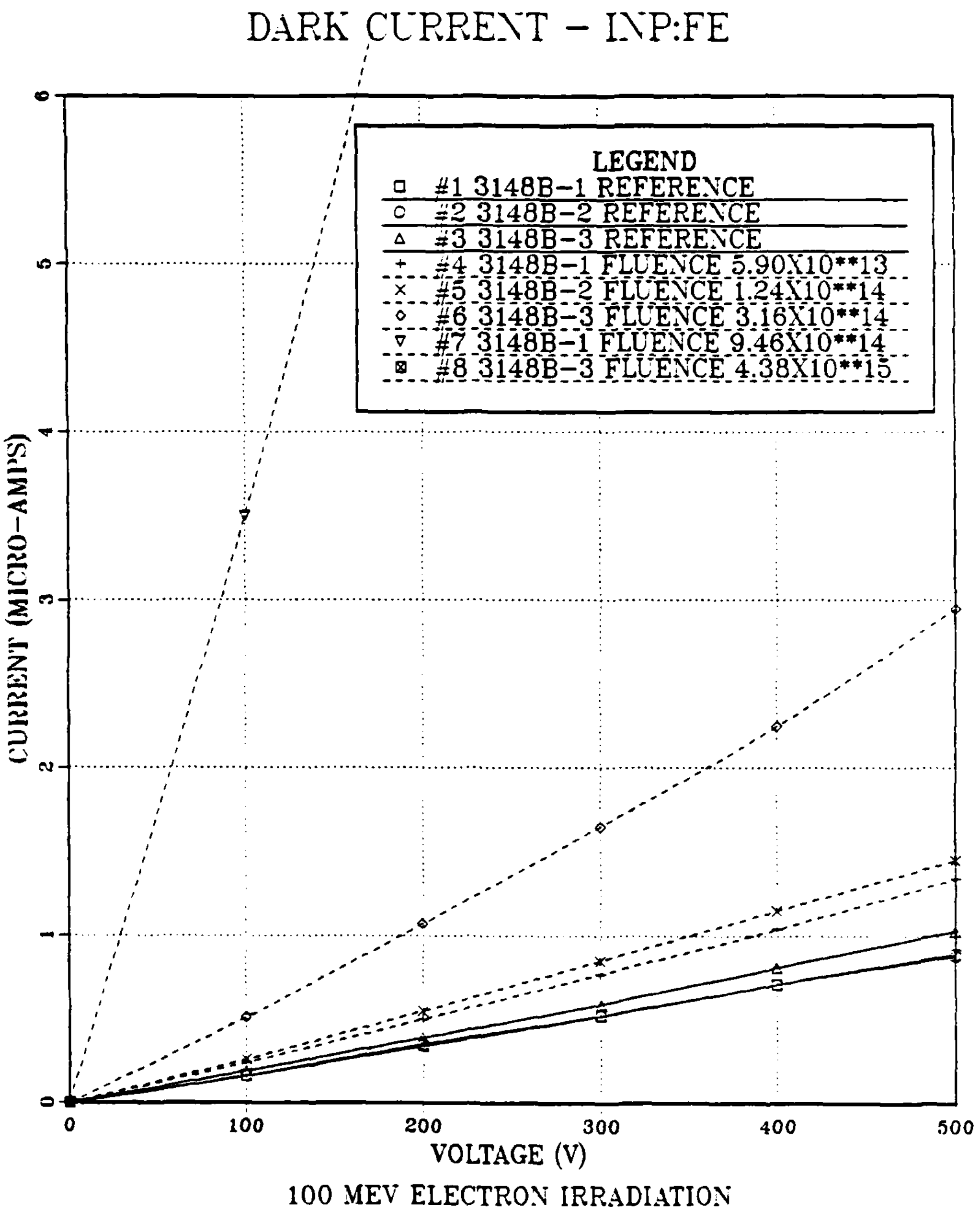


Figure 9. Dark Current--InP:Fe Ingot number: CCIPS-3148B
Data for curve #8 was not obtained due
to device breakdown at 5 volts

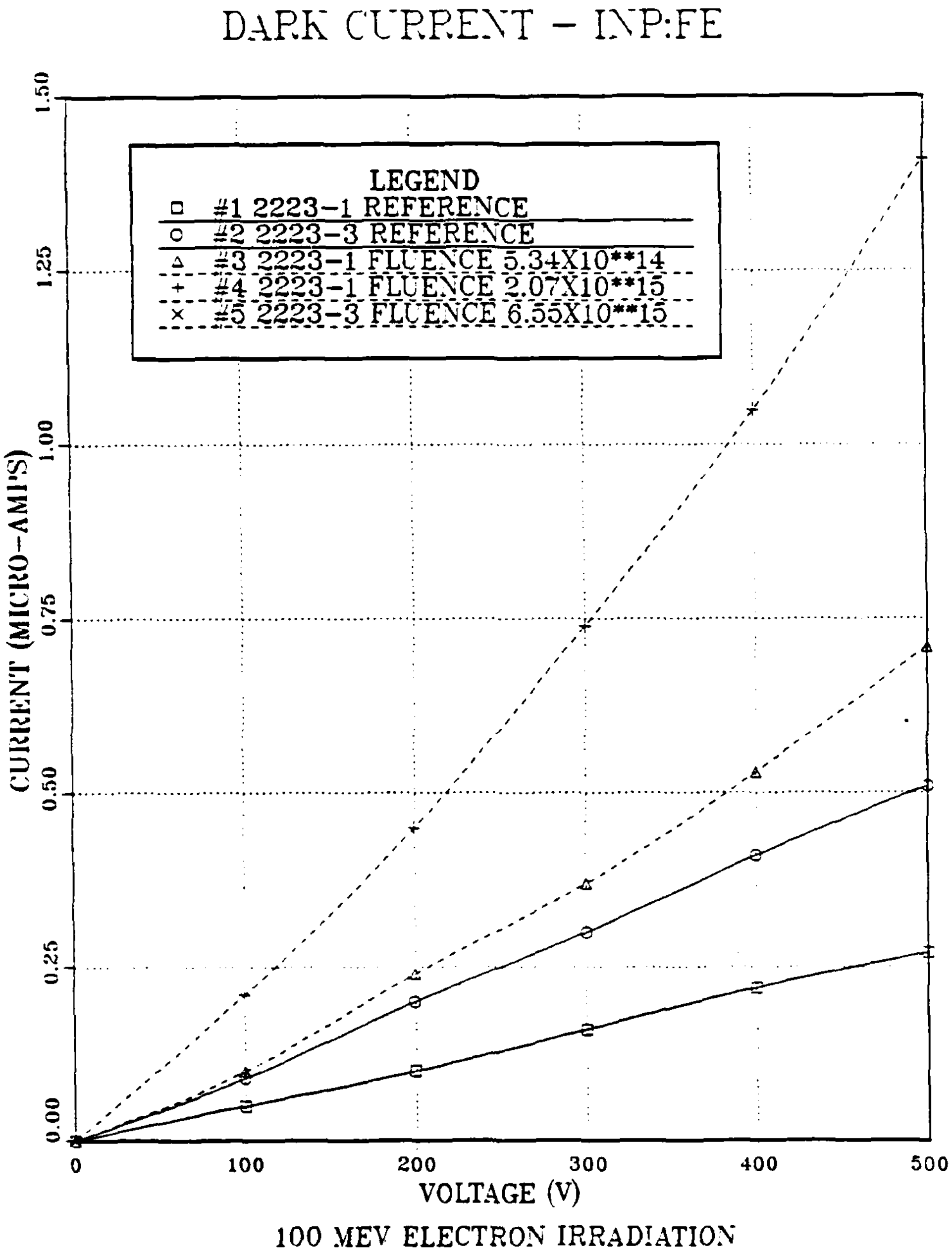


Figure 10. Dark Current--InP:Fe Ingot number: CCIPS-2223
Data for curve #5 was not obtained due to device breakdown at 50 volts

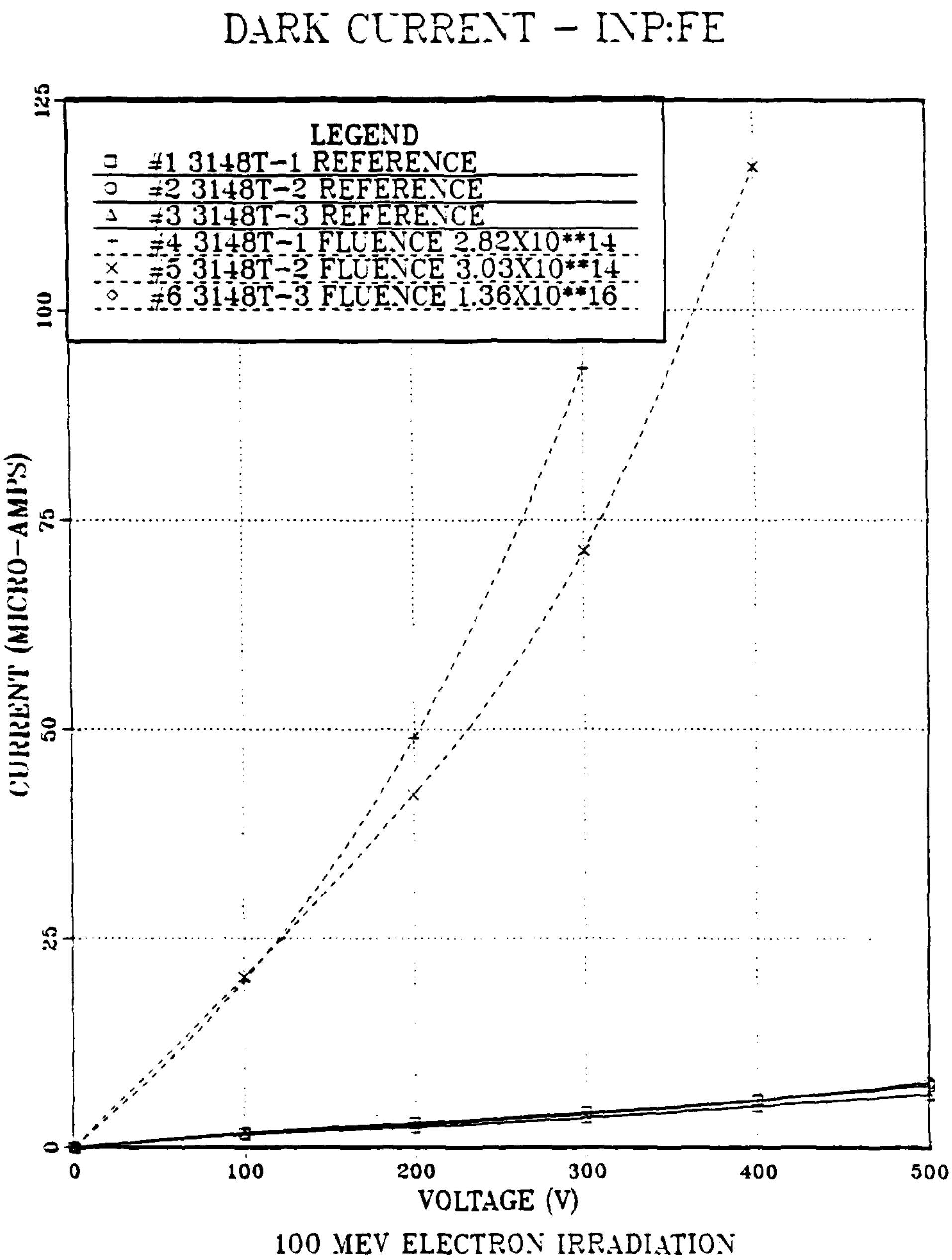


Figure 11. Dark Current--InP:Fe Ingot number: CCIPS-3149T
Data for curve #6 was not obtained due
to device breakdown at 39 volts

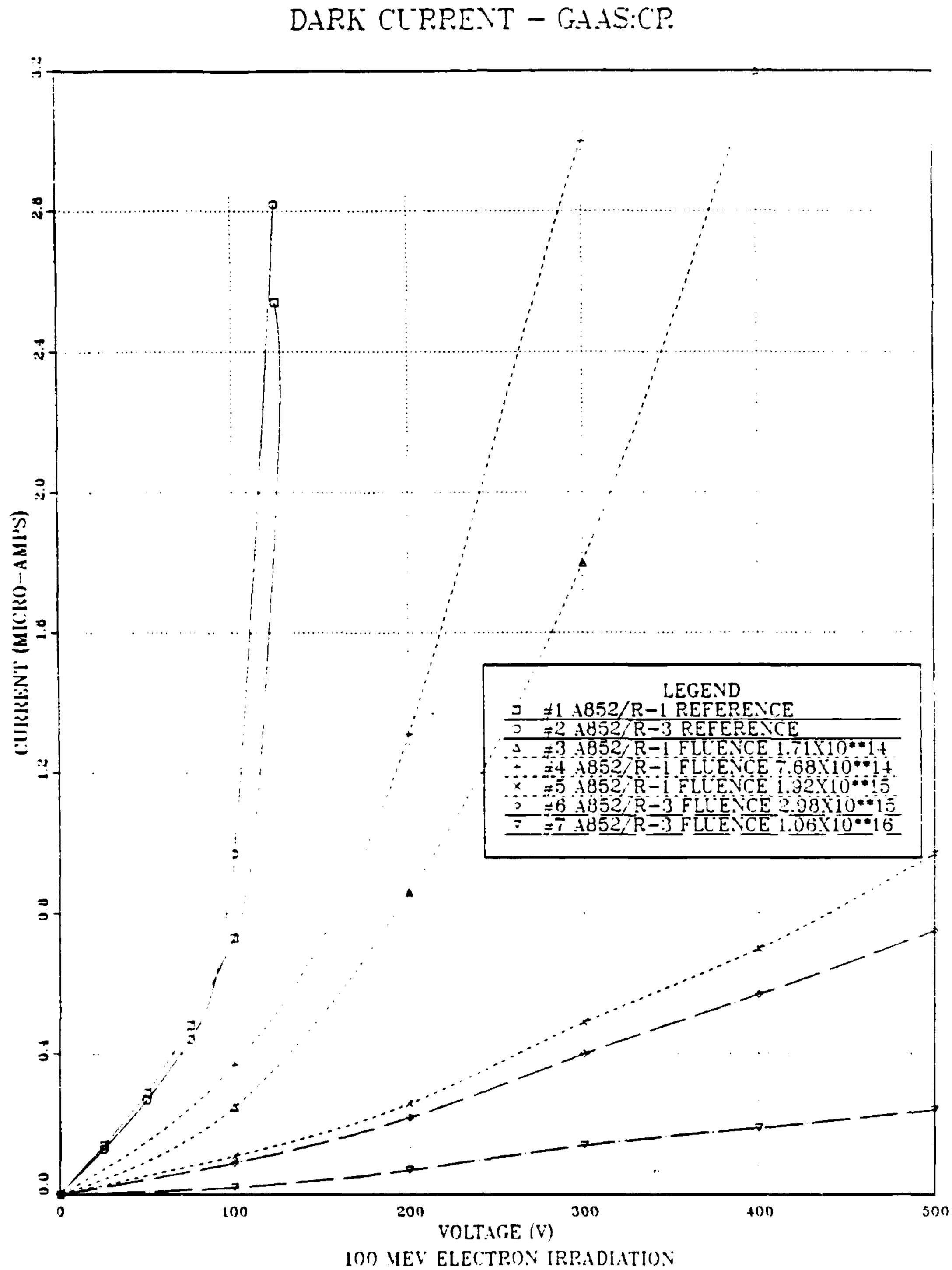


Figure 12. Dark Current--GaAs:Cr Ingot number: Cambridge--A852/R

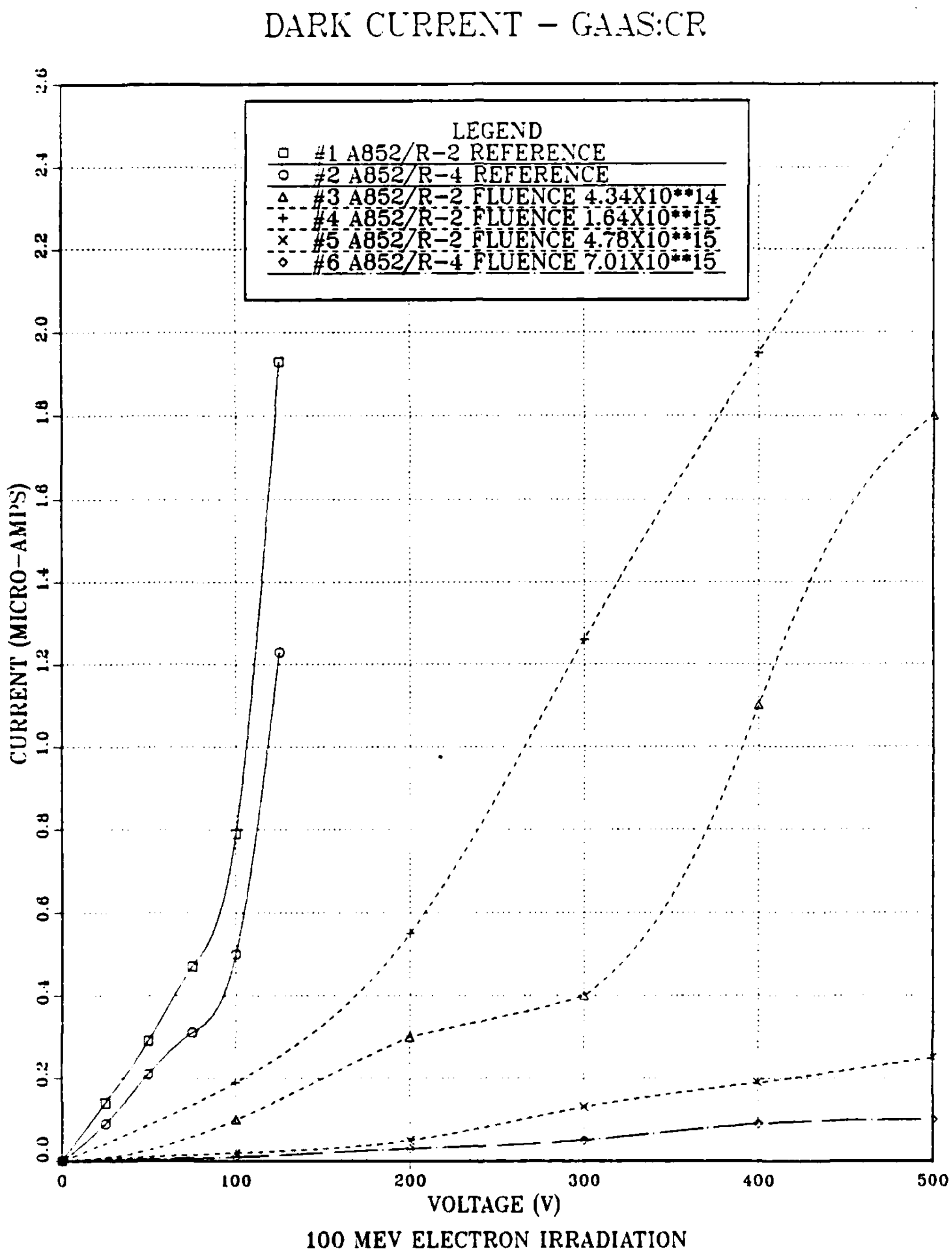


Figure 13. Dark Current--GaAs:Cr Ingot number: Cambridge-A852/R

TABLE 3

IMPULSE RESPONSE MEASUREMENTS

InP:Fe

	Sample #	Fluence (e/cm^2)	Total Dose RADS InP:Fe	Amplitude (mV) Pre Irradiation	Amplitude (mV) Post Irradiation	FWHM (ps) Pre Irradiation	FWHM (ps) Post Irradiation	Baseline (ns) Pre Irradiation	Baseline (ns) Post Irradiation
1	3148B-1	5.9×10^{13}	1.53×10^{6}	390	575	260	280	1.6	4.0
2	3148B-2	1.24×10^{14}	3.22×10^{6}	330	500	220	220	1.6	4.0
3	3148T-1	2.81×10^{14}	7.30×10^{6}	335.	450	600	260	9.0	5.0
4	3148T-2	3.03×10^{14}	7.87×10^{6}	230	480	520	240	5.5	6.0
5	3148B-3	3.16×10^{14}	8.21×10^{6}	385	380	260	240	1.6	4.0
6	2223-1	5.34×10^{14}	1.39×10^{7}	190	160	160	140	1.0	2.0
7	3148B-1	9.46×10^{14}	2.46×10^{7}	390	170	260	130	1.6	2.0
8	2223-1	2.07×10^{15}	5.37×10^{7}	190	088	160	135	1.0	1.3
9	3148B-3	4.38×10^{15}	1.13×10^{8}	385	---	260	---	1.6	---
10	2223-3	6.55×10^{15}	1.70×10^{8}	225	---	170	---	1.0	---
11	3148T-3	1.36×10^{16}	3.53×10^{8}	470	018	680	165	9.4	9.4

* Samples 1,2,5,7,9 Ingot: CCIPS # 3148-Bottom
3,4,11 Ingot: CCIPS # 3148-Top
6,8,10 Ingot: CCIPS # 2223

* --- Break down at applied voltages

TABLE 3 (CONTINUED)

GaAs:Cr

	Sample #	Fluence (e/cm^2)	Total Dose RADS GaAs:Cr	Amplitude (mV)		FWHM (ps)		Baseline (ns)	
				Pre Irradiation	Post Irradiation	Pre Irradiation	Post Irradiation	Pre Irradiation	Post Irradiation
1	A852/R-1	1.71×10^{14}	4.48×10^{6}	260	400	260	260	9.0	6.0
2	A852/R-2	4.34×10^{14}	1.14×10^{7}	285	280	255	210	9.0	5.0
3	A852/R-1	7.68×10^{14}	2.01×10^{7}	260	440	260	230	9.0	5.0
4	A852-R-2	1.64×10^{15}	4.30×10^{7}	285	340	255	220	9.0	4.0
5	A852/R-1	1.92×10^{15}	5.04×10^{7}	260	200	260	140	9.0	3.0
6	A852/R-3	2.98×10^{15}	7.81×10^{7}	285	144	240	180	9.0	4.0
7	A852/R-2	4.78×10^{15}	1.25×10^{8}	285	058	255	160	9.0	3.0
8	A852/R-4	7.01×10^{15}	1.83×10^{8}	275	025	250	140	9.0	2.5
9	A852/R-3	1.06×10^{16}	2.79×10^{8}	285	040	240	160	9.0	3.0

* All Samples   Ingot: Cambridge A852/R

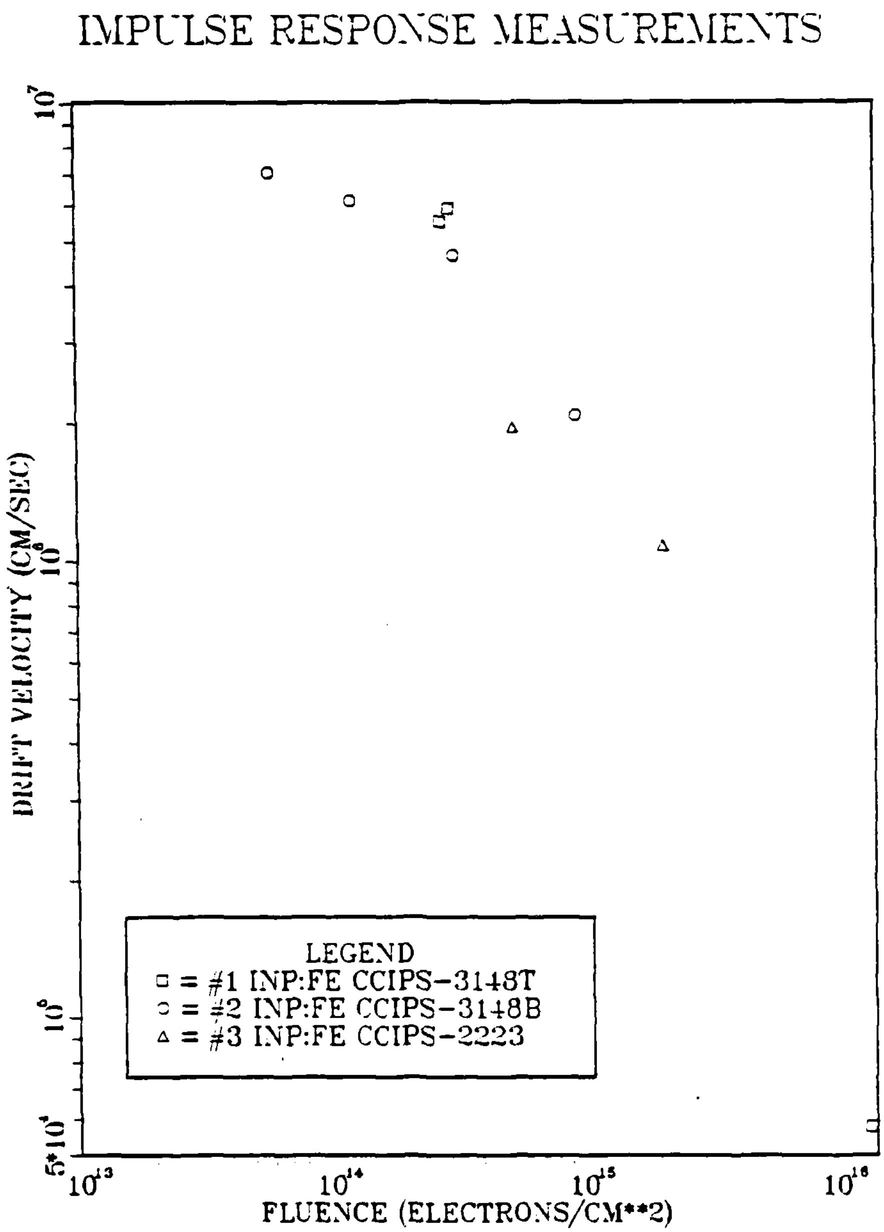


Figure 14. Impulse response measurement for InP:Fe Drift velocity

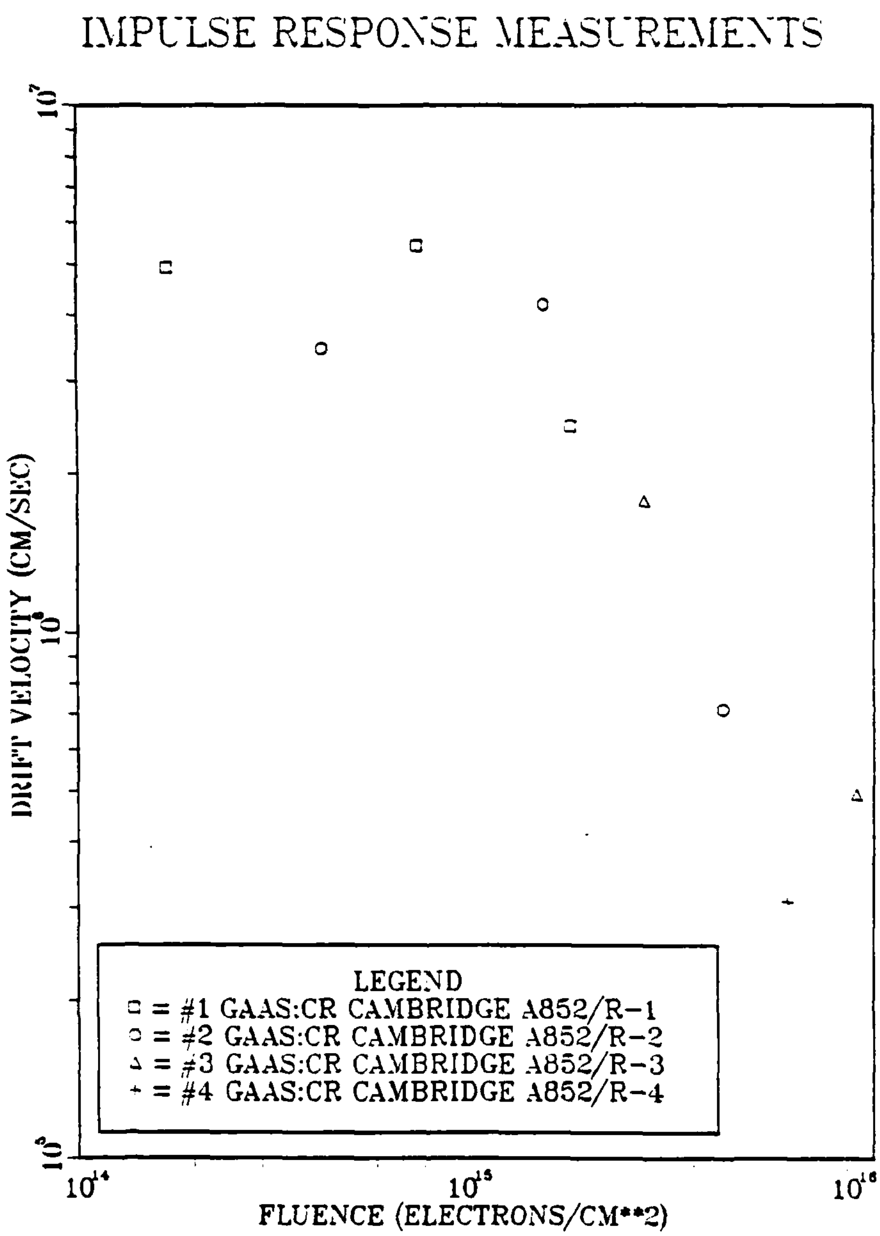


Figure 15. Impulse response measurement for GaAs:Cr Drift velocity

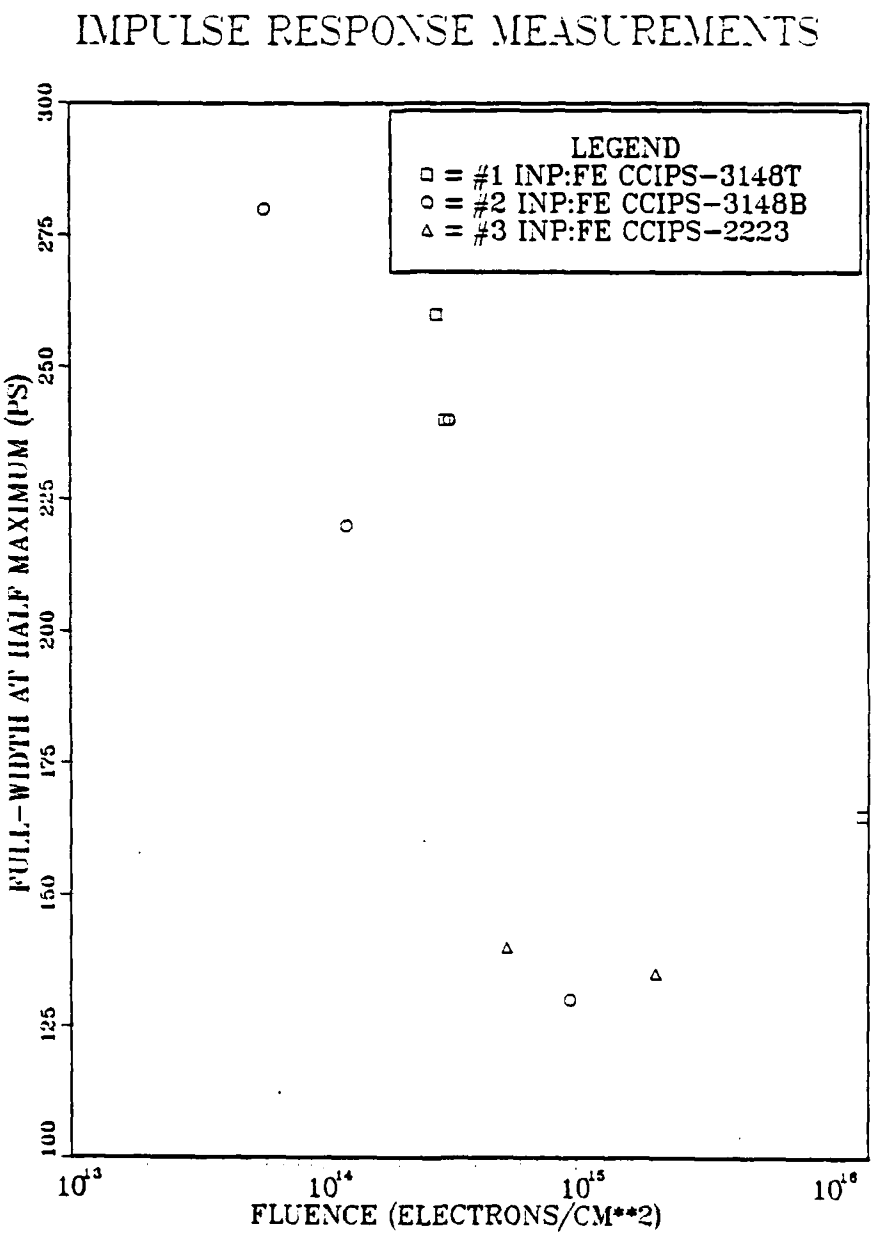


Figure 16. Impulse response measurement for InP:Fe Full-width at half maximum (response speed)

IMPULSE RESPONSE MEASUREMENTS

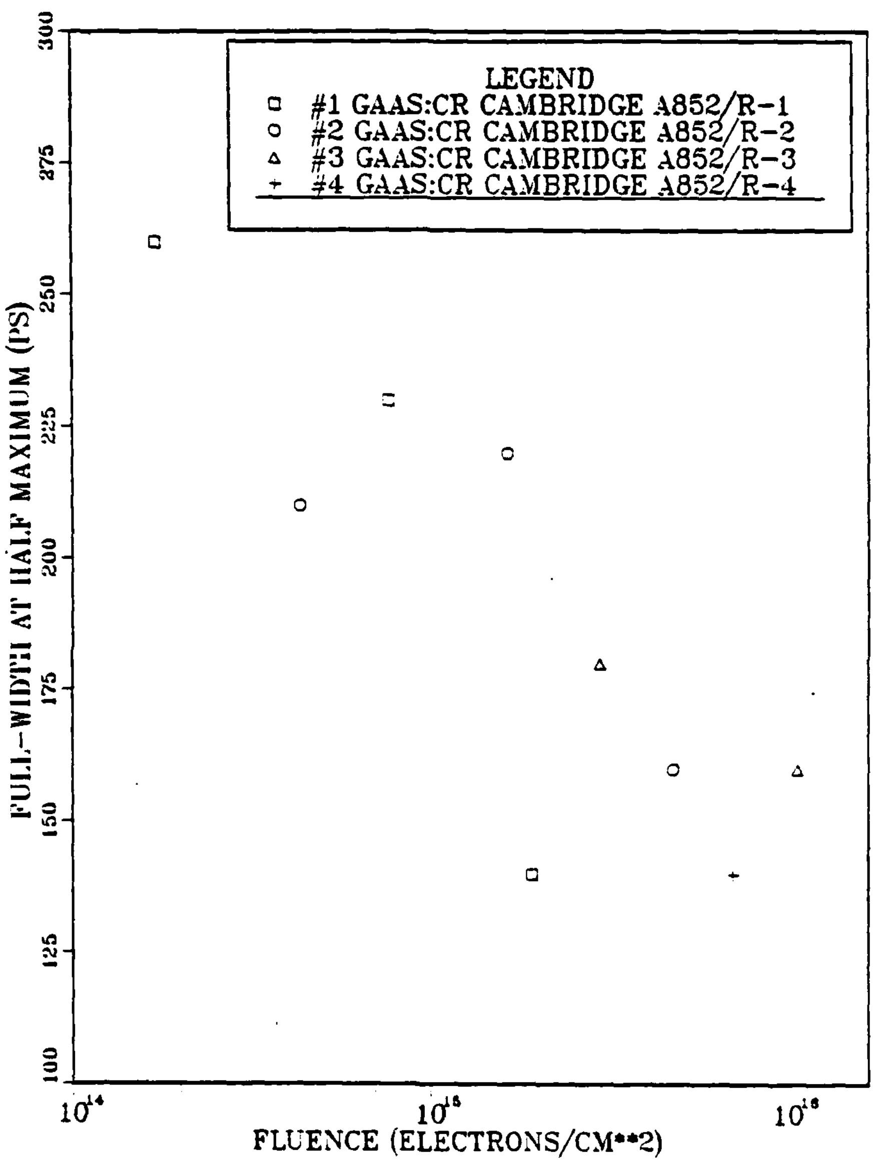
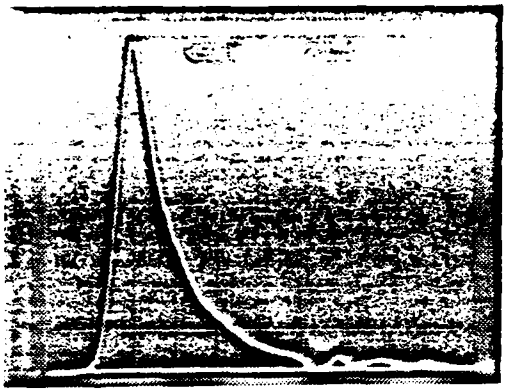
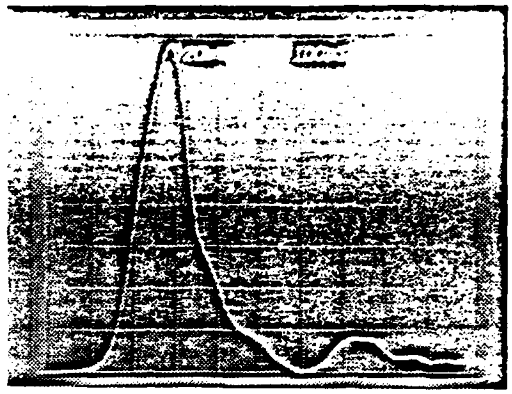


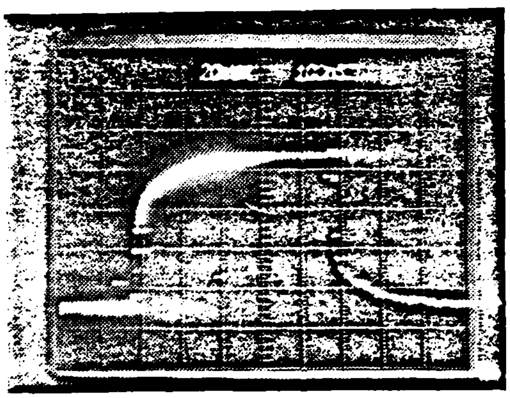
Figure 17. Impulse response measurement for GaAs:Cr Full-width at half maximum (response speed)



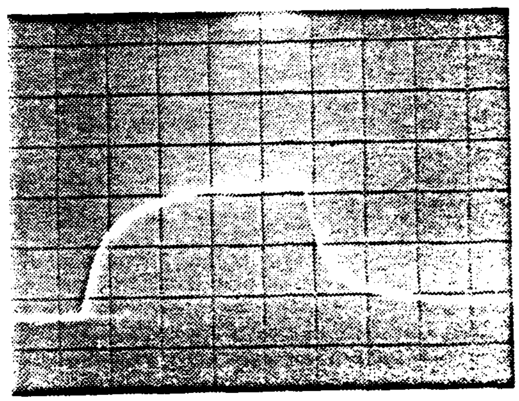
a) before irradiation impulse response FWHM 220-ps



b) after irradiation impulse response FWHM 140-ps

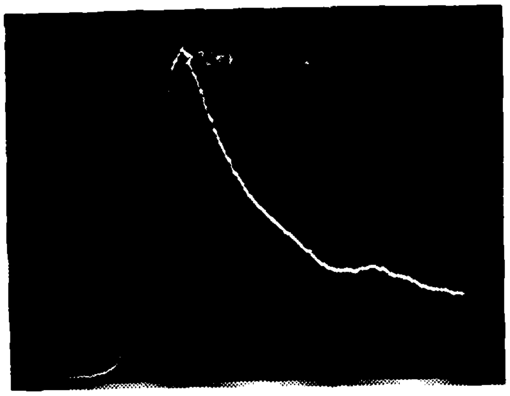


c) before irradiation square-pulse laser response

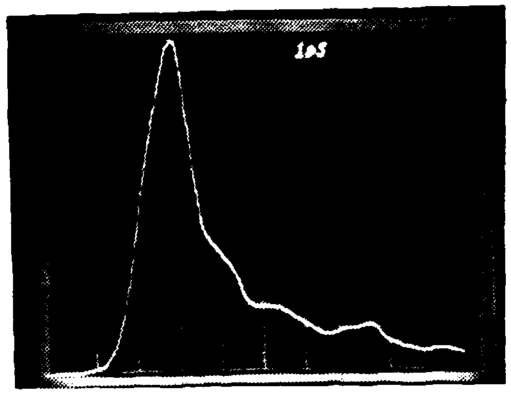


d) after irradiation square-pulse laser response

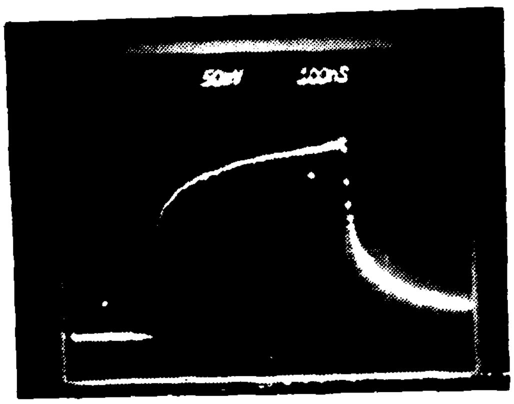
Figure 13. Comparison of InP:Fe impulse and square-pulse laser response before and after electron irradiation for a representative sample



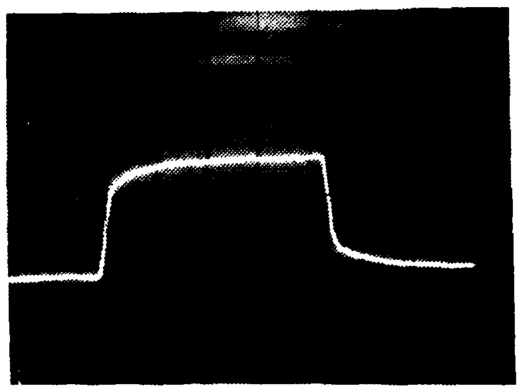
a) before irradiation impulse response FWHM 260-ps



b) after irradiation impulse response FWHM 140-ps



c) before irradiation square-pulse laser response



d) after irradiation square-pulse laser response

Figure 19. Comparison of GaAs:Cr impulse and square-pulse laser response before and after electron irradiation for a representative sample

TABLE 4

SQUARE-PULSE RESPONSE MEASUREMENTS

InP:Fe

	Sample #	Fluence (e/cm^2)	Total Dose RADS InP:Fe	Amplitude (mV) Pre Irradiation	Amplitude (mV) Post Irradiation	Risetime (10-90%) (ns) Pre Irradiation	Risetime (10-90%) (ns) Post Irradiation
1	3148B-1	5.9×10^{13}	1.53×10^{6}	092	012	100	180
2	3148B-2	1.24×10^{14}	3.22×10^{6}	076	008	080	180
3	3148T-1	2.81×10^{14}	7.30×10^{6}	380	030	120	180
4	3148T-2	3.03×10^{14}	7.87×10^{6}	270	024	140	190
5	3148B-3	3.16×10^{14}	8.21×10^{6}	106	007	160	190
6	2223-1	5.34×10^{14}	1.39×10^{7}	034	026	180	200
7	3148B-1	9.46×10^{14}	2.46×10^{7}	092	028	100	210
8	2223-1	2.07×10^{15}	5.37×10^{7}	034	013	180	230
9	3148B-3	4.38×10^{15}	1.13×10^{8}	106	---	160	---
10	2223-3	6.55×10^{15}	1.70×10^{8}	046	---	140	---
11	3148T-3	1.36×10^{16}	3.53×10^{8}	540	---	080	---

* Samples 1,2,5,7,9 Ingot: CCIPS # 3148-Bottom
3,4,11 Ingot: CCIPS # 3148-Top
6,8,10 Ingot: CCIPS # 2223

* --- Break down at applied voltages

TABLE 4 (CONTINUED)

GaAs:Cr

Sample #		Fluence (e/cm^2)	Total Dose RADS GaAs:Cr	Amplitude (mV)		Risetime (10-90%) (ns)	
				Pre Irradiation	Post Irradiation	Pre Irradiation	Post Irradiation
1	A852/R-1	1.71×10^{14}	4.48×10^{6}	240	036	220	260
2	A852/R-2	4.34×10^{14}	1.14×10^{7}	250	120	240	140
3	A852/R-1	7.68×10^{14}	2.01×10^{7}	240	065	220	200
4	A852/R-2	1.64×10^{15}	4.30×10^{7}	250	028	240	050
5	A852/R-1	1.92×10^{15}	5.04×10^{7}	240	007	220	080
6	A852/R-3	2.98×10^{15}	7.81×10^{7}	170	034	120	080
7	A852/R-2	4.78×10^{15}	1.25×10^{8}	250	009	240	040
8	A852/R-4	7.01×10^{15}	1.83×10^{8}	200	020	220	040
9	A852/R-3	1.06×10^{16}	2.79×10^{8}	170	040	120	040

* All Samples Ingot: Cambridge A852/R

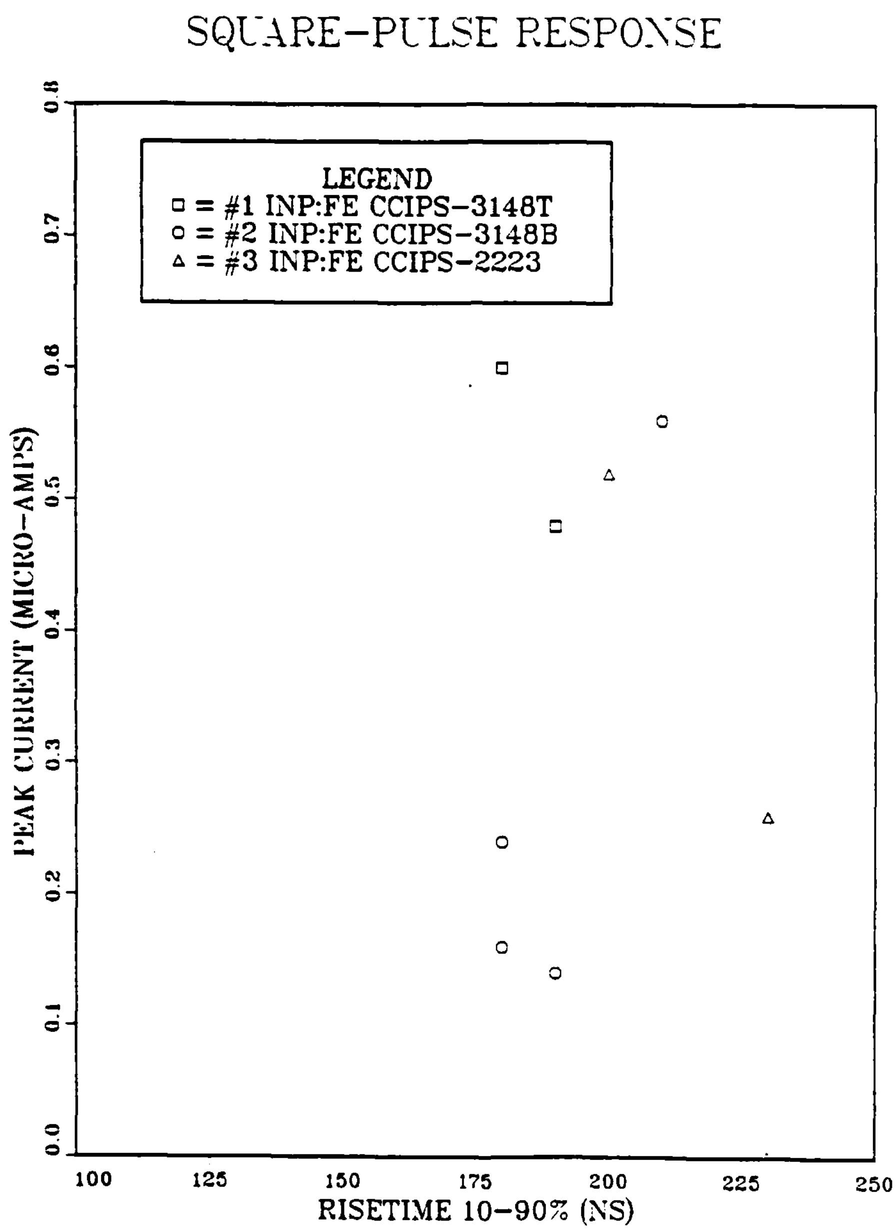


Figure 20. Square-pulse response measurement for InP:Fe Peak current vs Risetime (10%-90%)

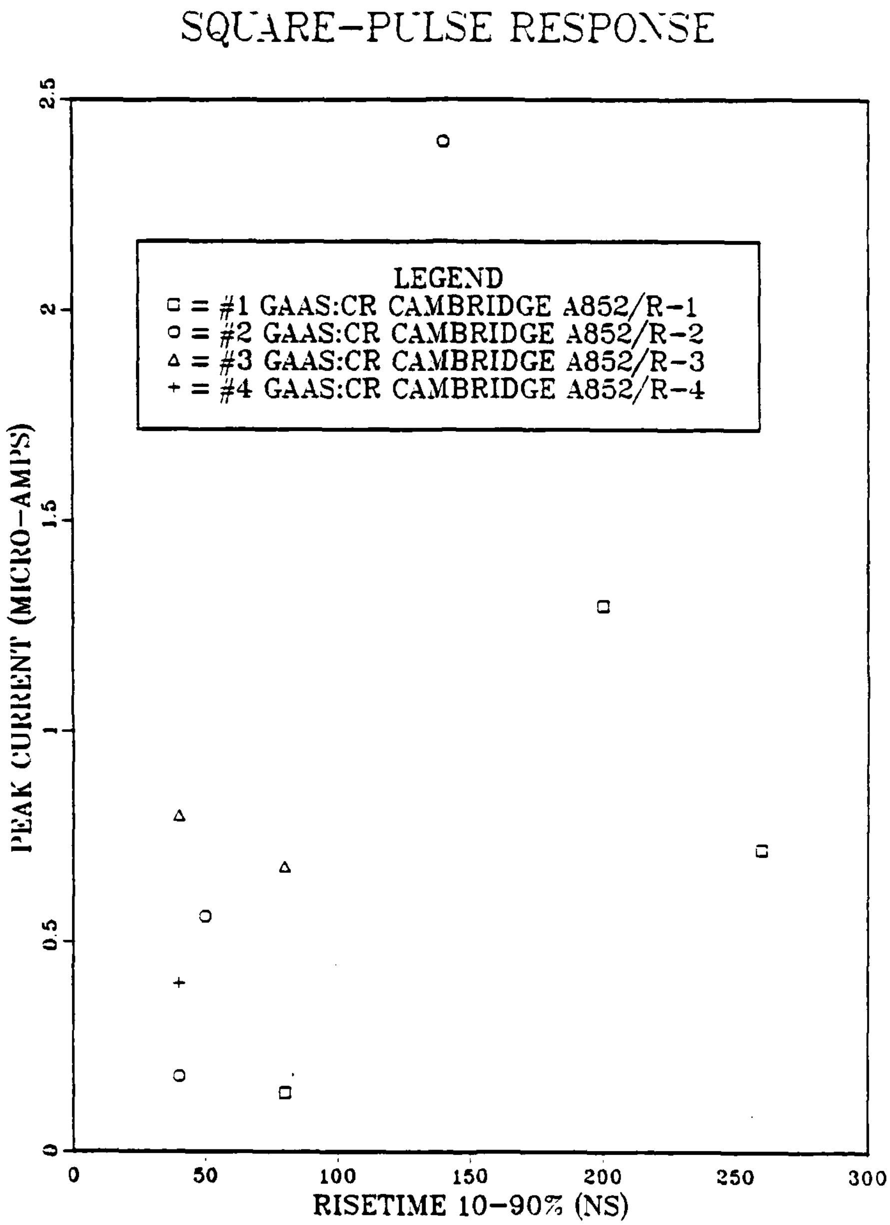


Figure 21. Square-pulse response measurement for GaAs:Cr Peak Current vs Risetime (10%-90%)

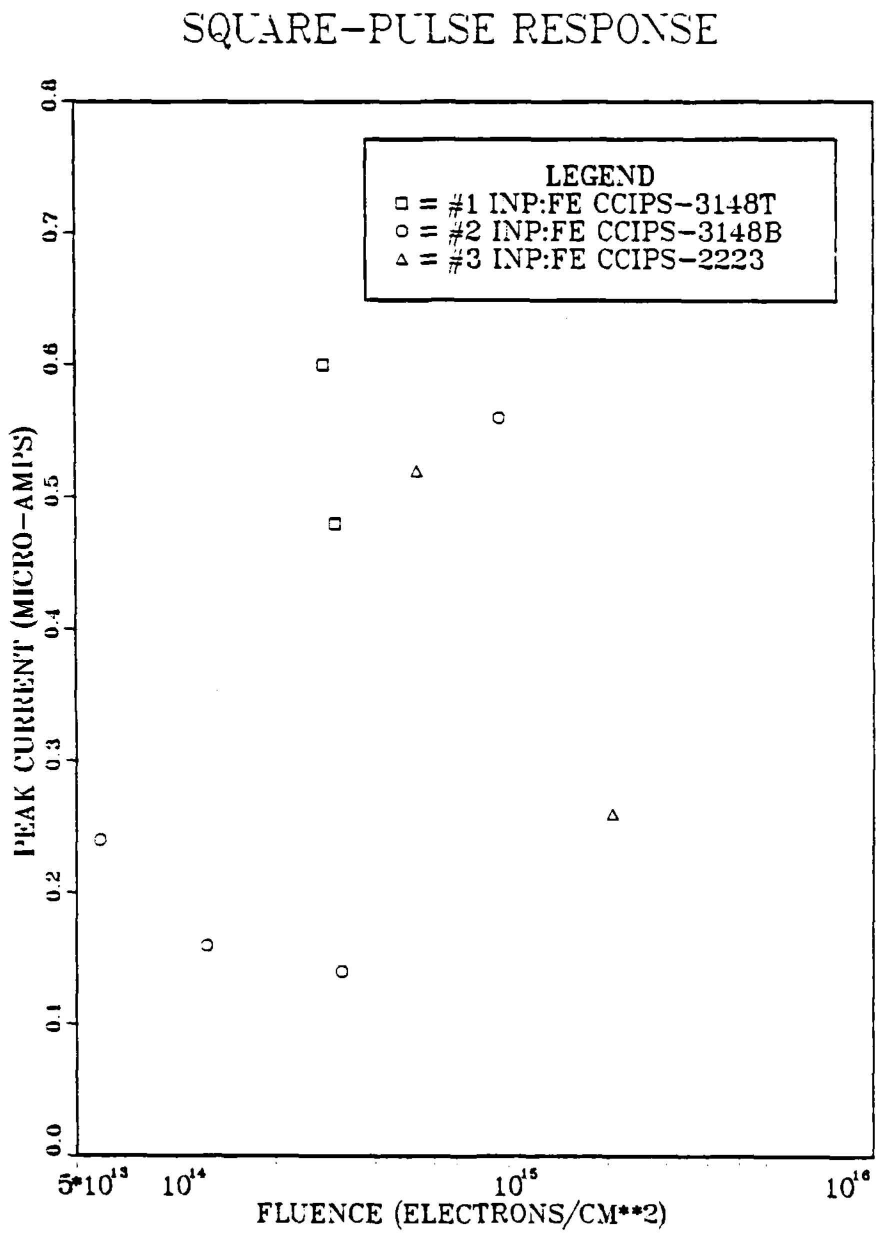


Figure 22. Square-pulse response measurement for InP:Fe Peak current vs Fluence

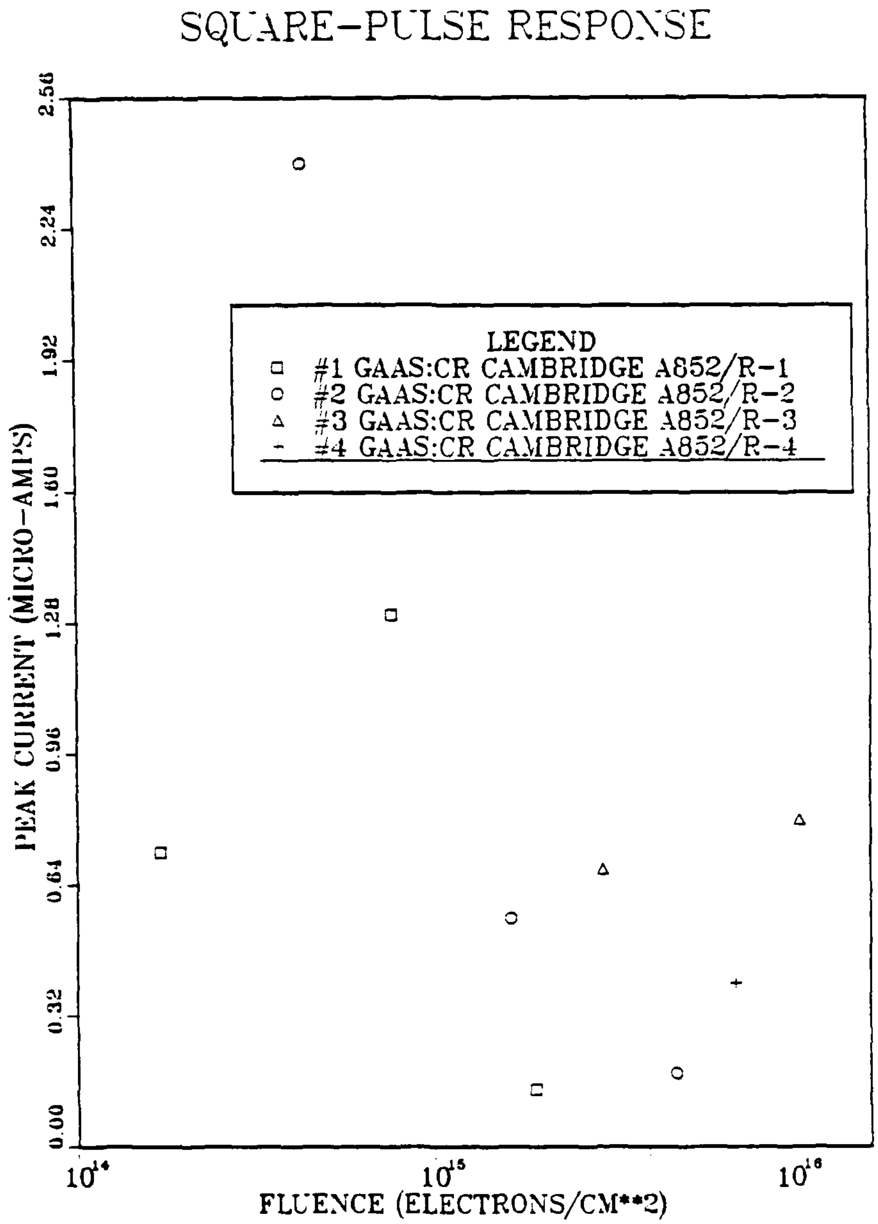


Figure 23. Square-pulse response measurement for GaAs:Cr Peak current vs Fluence

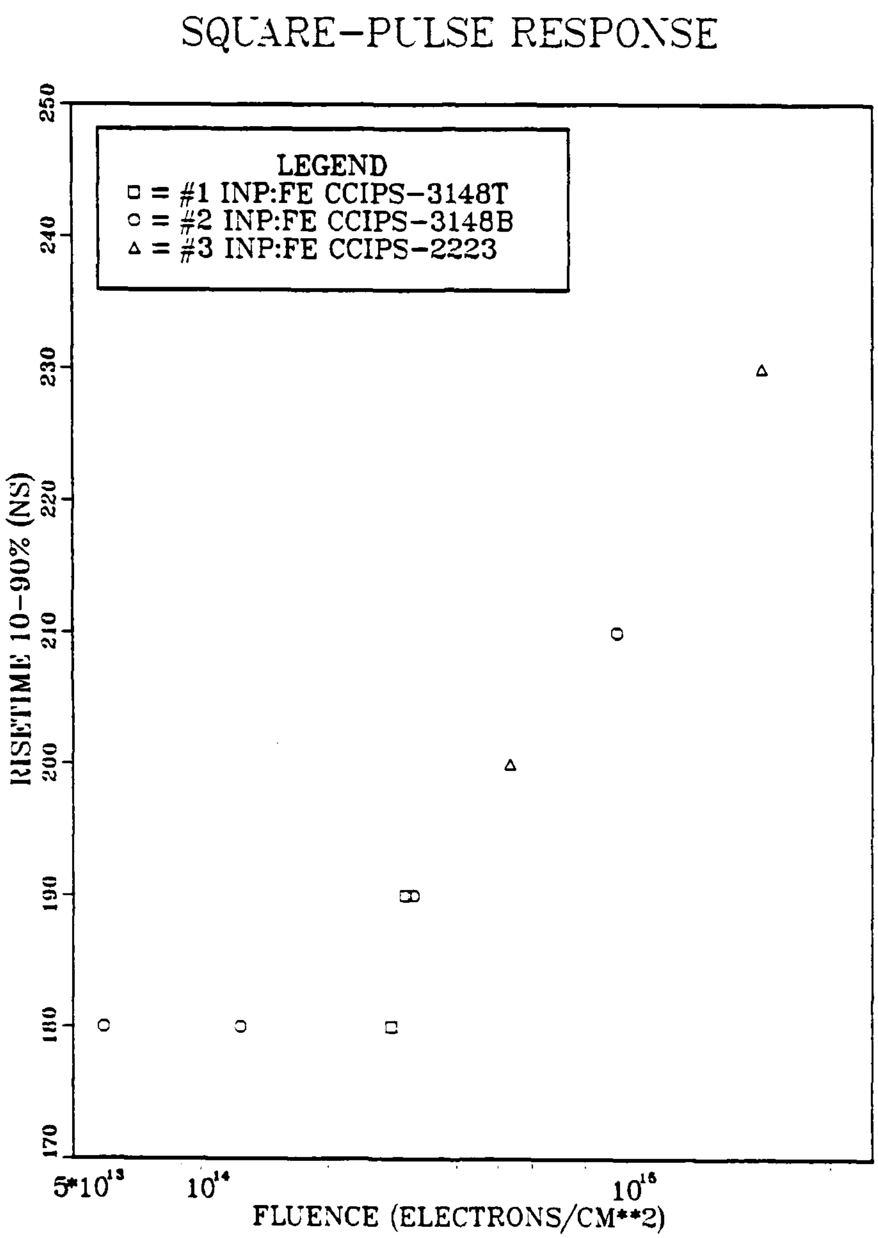


Figure 24. Square-pulse response measurement for InP:Fe Risetime (10%-90%) vs Fluence

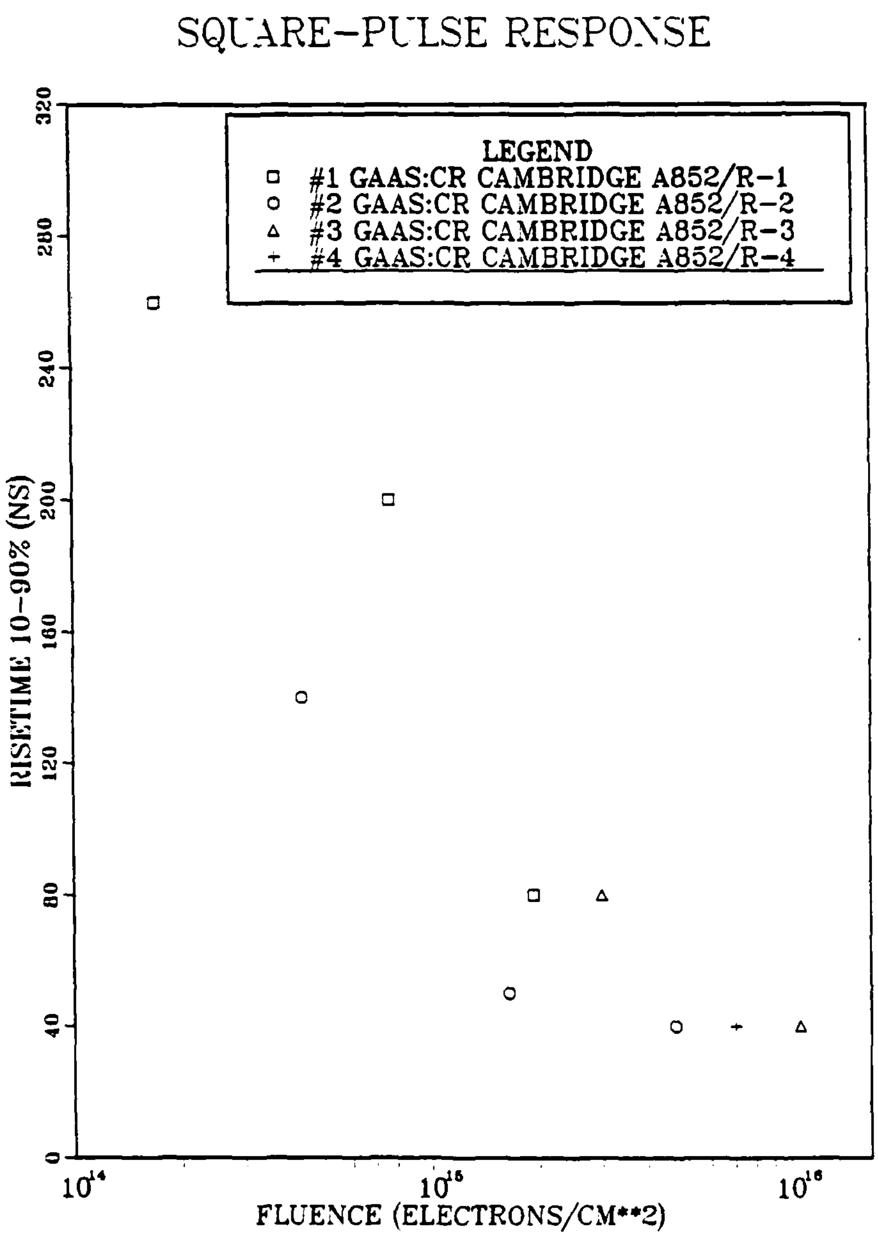


Figure 25. Square-pulse response measurement for GaAs:Cr Risetime (10%-90%) vs Fluence

IV. EXPERIMENTAL RESULTS

A. DARK CURRENT

Dark current measurements taken before and after the 100 MeV electron irradiation were compared to determine the resulting change. Figures 9 through 13 display the results. The mode of preparation and impurity content of the material results in variation of the recombination lifetime [Ref. 16]. Since decay times are inversely proportional to the Fe dopant levels in InP:Fe [Ref. 25], samples were segregated depending on the source Ingot and whether the samples were prepared from the top or the bottom of a given Ingot. Higher dopant levels in the bottom of an Ingot are due to gravitational forces. Comparison of reference dark current measurements justify this segregation. All the GaAs:Cr samples were prepared from the same portion of the same Ingot.

Before irradiation, the InP:Fe samples were biased up to 500 volts in 100 volt increments and results indicate a linearity through 500 volts. The GaAs:Cr samples were biased up to 125 volts in 25 volt increments. They lose linearity at approximately 100 volts. Post-irradiation measurements indicate a noticeable change in the dark current. The InP:Fe sample results indicate an increase in dark current for the applied voltages. The amount of increase depends on the fluence with higher fluence yielding higher dark currents. The GaAs:Cr samples show a decrease in dark current with higher fluence.

B. IMPULSE RESPONSE

Impulse response measurements for pre and post 100 MeV electron irradiation are listed in Table 3. Included in these measurements are: 1) amplitude--from which I (peak current) can be determined thus allowing for the determination of electron mobility and electron drift velocity, 2) full-width at half maximum (FWHM)--from which carrier relaxation time (response speed) is resolved, and 3) baseline tail--which gives an indication of whether the detector returns to its reference point after having been excited by the photon source, and if so, within what time period.

Both the InP:Fe and GaAs:Cr samples are affected by the irradiations with the more pronounced effects resulting from the higher fluence. Figures 14 and 15 are graphs of the effective carrier drift velocity derived from Formulas 21 and 22. In these equations, electrons are assumed to be the carrier type due to the much higher drift velocities. The measured values of the peak current response are used along with the following experimental parameters: 1) reflectivity (R_r) is 30 percent, 2) the contact spacing (S) is equal to the .5 mm gap, 3) the energy necessary to create an electron-hole pair is assumed to be 5 eV, 4) the applied voltage (V_{appl}) is 200 Volts for InP:Fe and 100 Volts for GaAs:Cr, 5) q is the electronic charge and 6) the optical energy deposited into the detector by the incident photon source (E) is approximately 580 pJ. The effective drift velocity is then calculated by

$$V_d = \mu E_f \qquad (25)$$

where E_f = 4 kV/cm for InP:Fe and 2 kV/cm for GaAs:Cr. Both figures show a decrease in the carrier drift velocity with increasing fluence. This suggests that electron mobility and electron drift velocity are inversely proportional to the incident electron fluence.

The response speed of the photoconductive detector is determined by the full-width at half maximum (FWHM) measurement of the impulse response. The trend of decreasing response time (decreasing FWHM) with increased fluence is summarized for both material types in Figures 16 and 17. These results are predictable due to the increased number of trapping and recombination centers created by the displacement damage. Figures 18 and 19 display a representative sample of the impulse response before and after irradiation for InP:Fe and GaAs:Cr respectively.

For the GaAs:Cr samples, all baseline tails were reduced. The InP:Fe sample results indicate that there was either no improvement or an increase in the baseline tails.

C. SQUARE-PULSE RESPONSE

Square-pulse response measurements for pre and post 100 MeV electron irradiation are listed in Table 4. Measurements include: 1) amplitude--from which I (peak current) is determined and 2) risetime (10%-90%) which gives an indication of the time involved for saturation of the neutral acceptor states by electrons and the simultaneous recombination of the negatively charged acceptor states by holes.

Figures 18 and 19 display a representative sample of the square-pulse measurement before and after irradiation for InP:Fe and GaAs:Cr respectively. Both material types show square-pulse nonlinearities for the pre-irradiated samples. After irradiation, the GaAs:Cr samples display significant improvement in accurately following the longer events. The quality of improvement is commensurate with higher fluence. This response is not found in the InP:Fe samples, but rather, an increase in nonlinearity for higher fluence. The dependency of peak current on risetime or fluence was not established for either material type as displayed in Figures 20 through 23. Risetime vs fluence is plotted in Figures 24 and 25. These graphs suggest a proportional relationship for fluence above 2.81×10^{14} (electrons/cm^2) for the InP:Fe samples and an inversely proportional relationship for fluence below 4.78×10^{15} (electrons/cm^2) for the GaAs:Cr samples.

D. COMPUTER SIMULATION

A computer simulation of a 100 MeV electron beam incident on a rectangular parallelepiped (RPP) semiconductor target was performed using the CRAY computer located at the Los Alamos National Laboratory. The ACCEPT code, one of the ITS: The Integrated TIGER Series of Coupled Electron/Photon Monte Carlo Transport Codes, was used. The ACCEPT input program along with the Cross Section Generations and the Monte Carlo executions for both the InP:Fe and GaAs:Cr samples is enclosed.

Quoting from the description of the code, "ITS is a Monte Carlo solution of linear time-integrated coupled electron photon radiation problems. The ETRAN model was used as the basis. It combines microscopic photon transport with a macroscopic random walk for electron transport. The ACCEPT code is a general three-dimensional transport code that uses a combinational geometry scheme" [Ref. 26].

The results in graphic form (normalized to one particle) for both electrons and photons are displayed in Figures 26 through 31. Both materials give similar results. It is obvious from the Angular Distribution graphs (Figures 26 and 27) that the overwhelming majority of both electrons and photons occur at an angle between 0 and 10 steradians. This would indicate that there is very little deflection of the incident electrons or the resulting photons. The Energy Spectra of the escaping electrons (Figure 28) indicate that most are leaving the target with energies between 90-100 MeV, therefore, only a small percentage of the total energy is actually deposited into the device. The actual energy deposition per electron is $1.762 \cdot 10^{-2}$ MeV (1.476×10^{11} RADS-InP Coul) for InP:Fe and 1.993×10^{-2} MeV (1.500×10^{11} RADS-GaAs/Coul) for GaAs:Cr. The charge deposition is -2.059×10^{-3} for InP:Fe and -1.993×10^{-3} for GaAs:Cr. Most of the photons are in the low energy range (Figure 29). The Flux Distributions (Figures 30 and 31) substantiate these results with the highest flux for electrons in the high energy regions whereas the highest flux for photons is in the lower energy regions. The results are not surprising given the thickness of

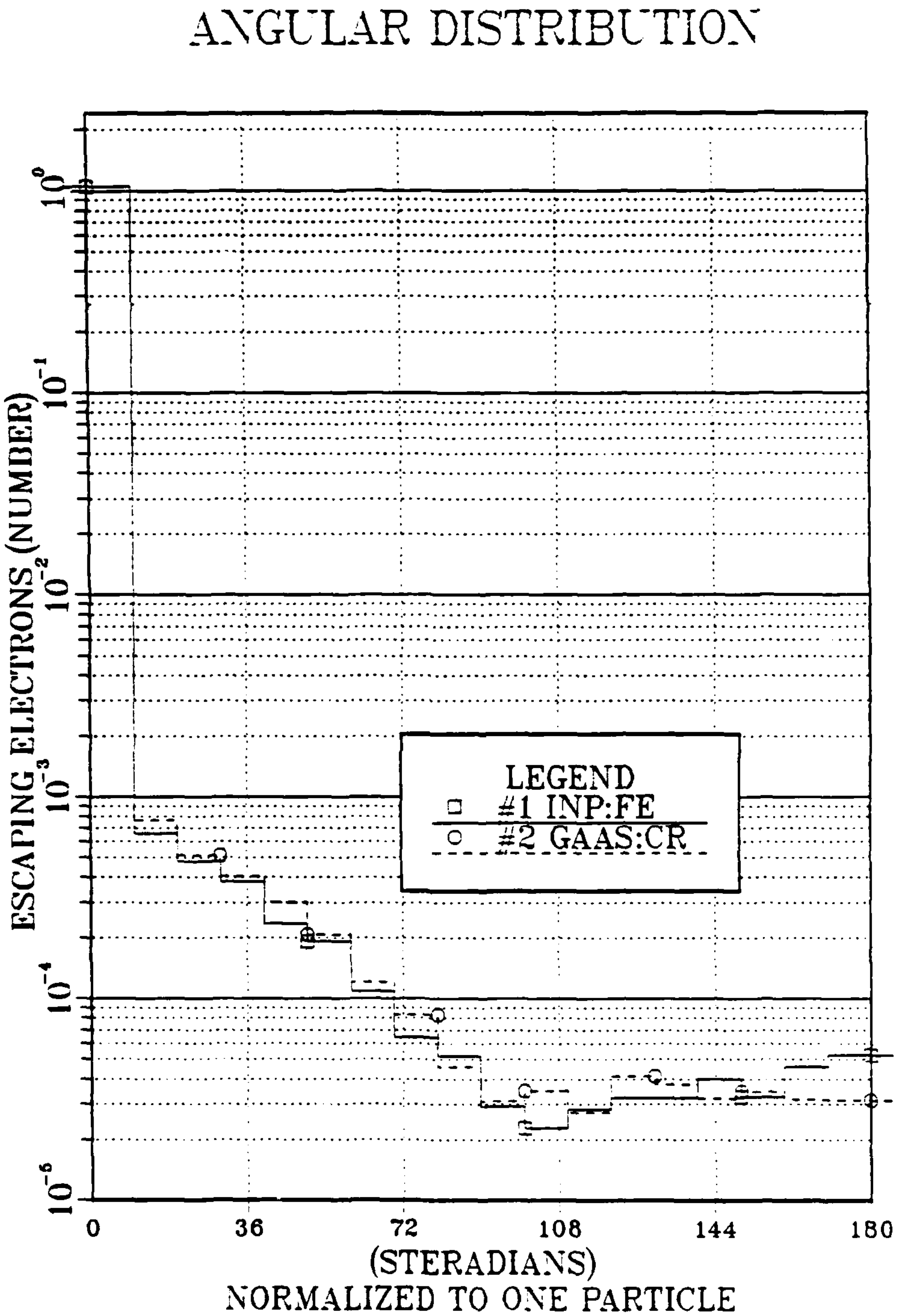


Figure 26. Angular Distribution (Electrons)

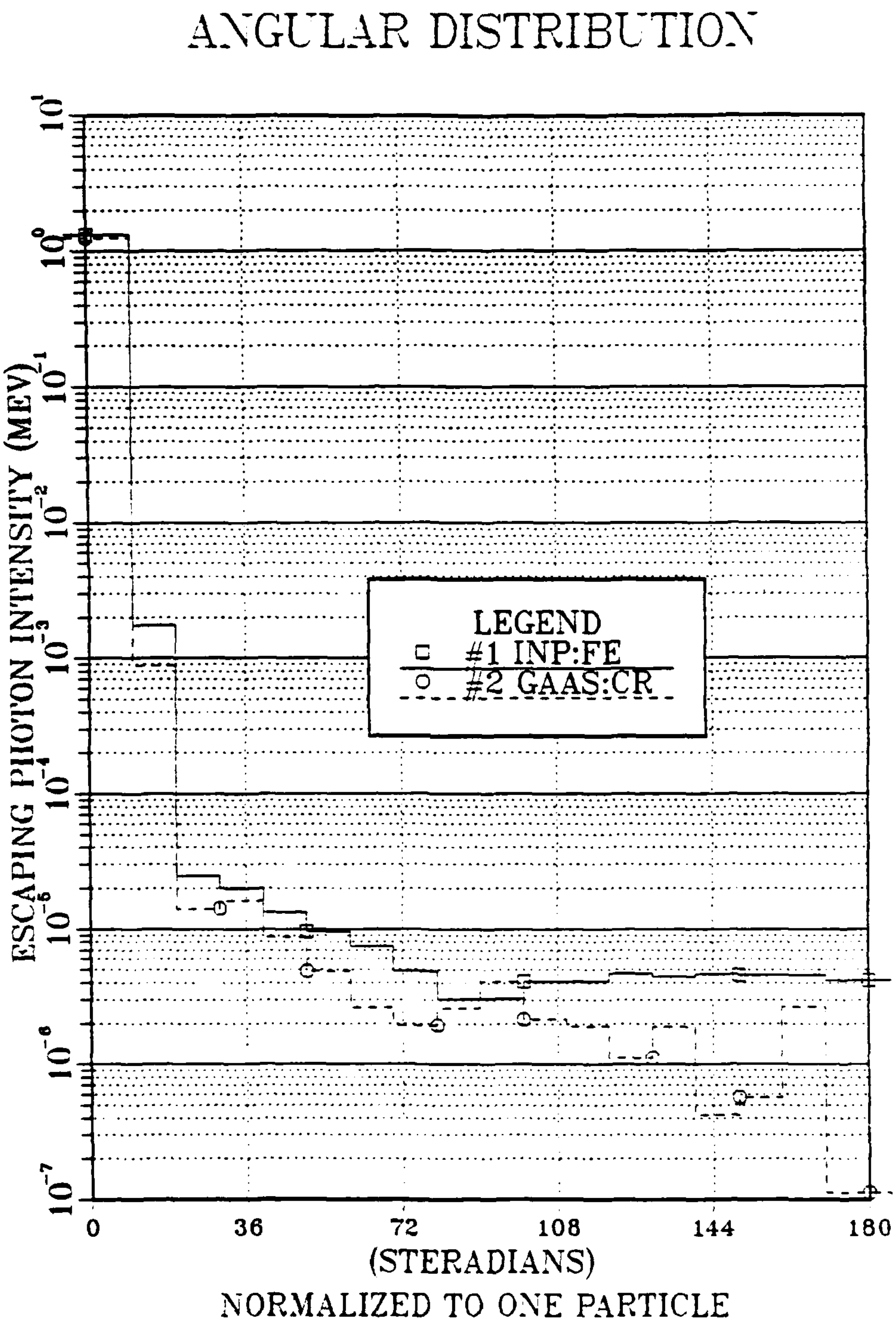


Figure 27. Angular Distribution (Photons)

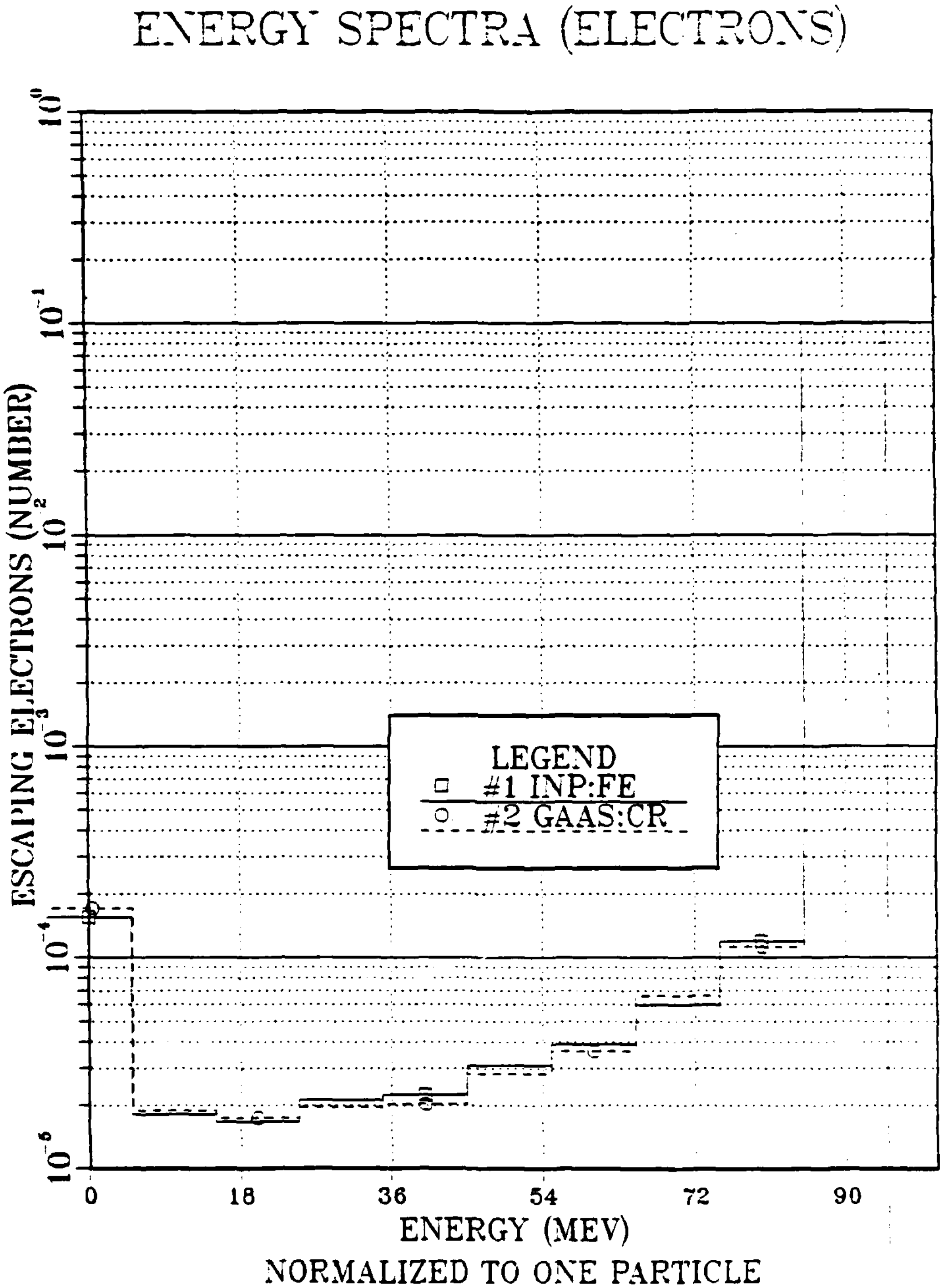


Figure 28. Energy Spectra (Electrons)

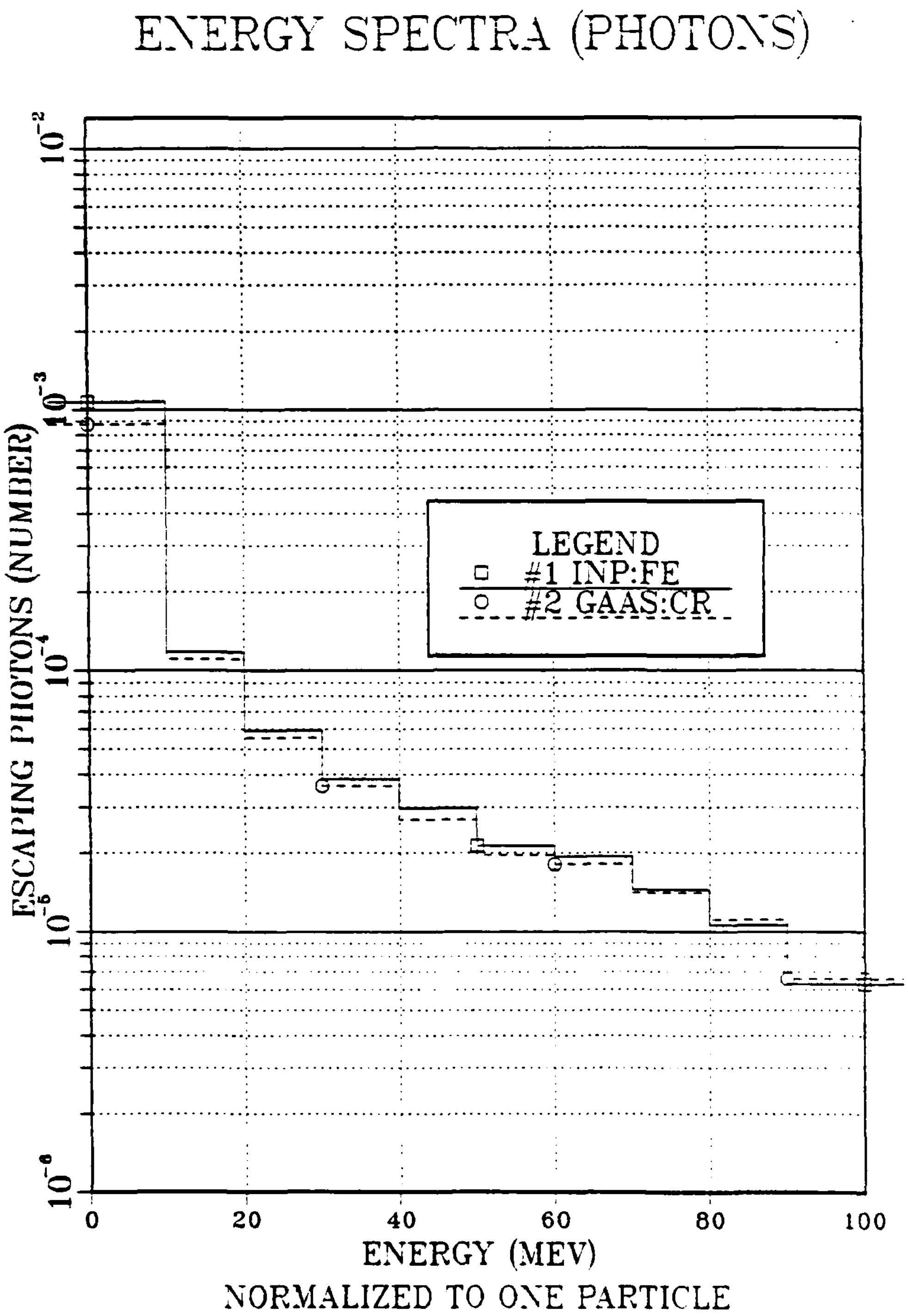


Figure 29. Energy Spectra (Photons)

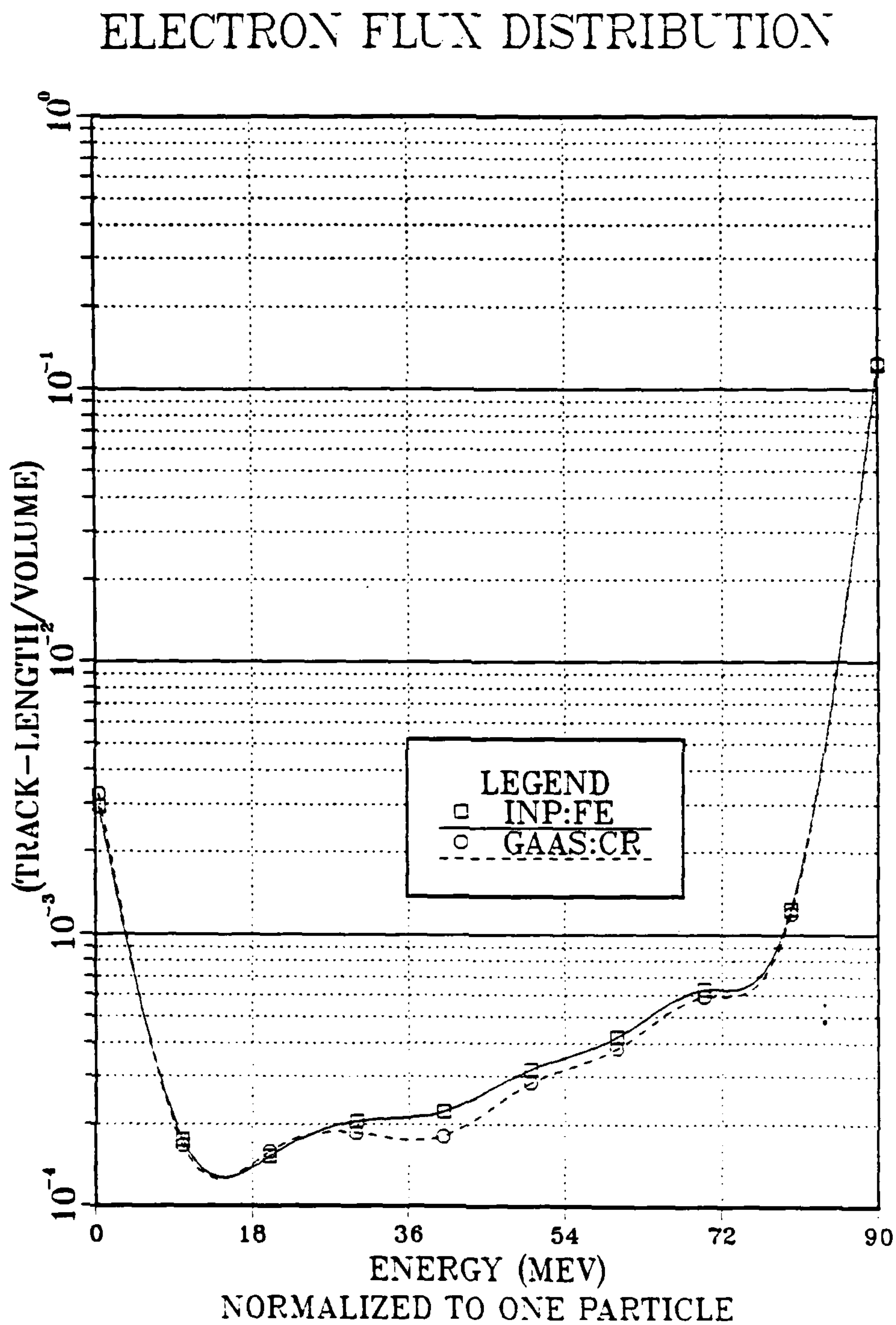


Figure 30. Electron Flux Distribution

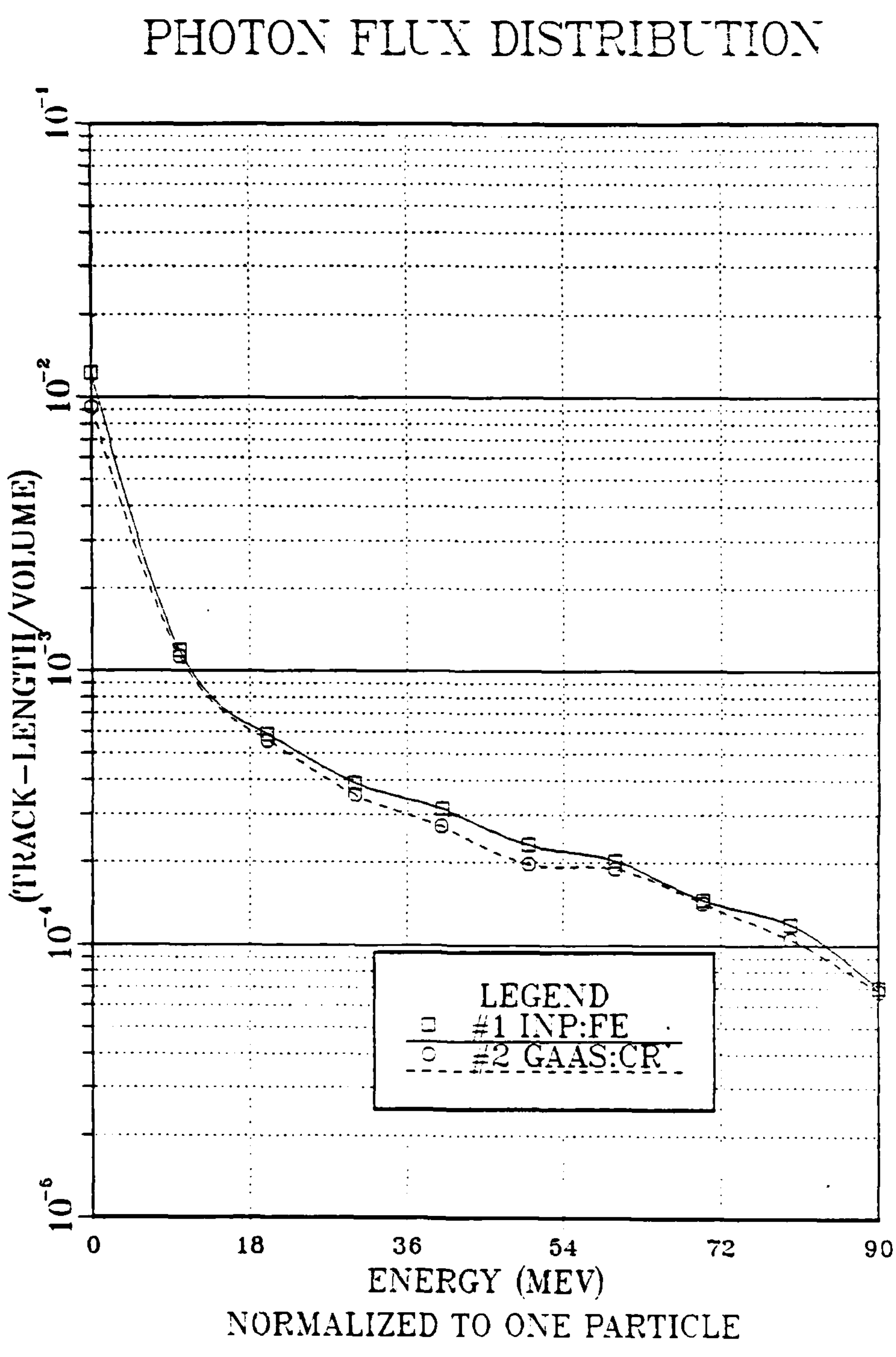


Figure 31. Photon Flux Distribution

the sample (thin sample) and the energy of the incident electrons thus legitimizing the use of thin sample approximations. Included in the Monte Carlo executions are listings of the physical options based on 10 batches of 100,000 histories each. Bremsstrahlung represents the highest number generated, more than all others combined.

E. DISPLACEMENTS

In determining the number of displacements from formulas 5-10, an equal probability of collision for the secondary atoms was assumed. Since these devices are compounds, a range of the displacement cross section and therefore a range of the number of displacements is accounted for through the Threshold Displacement Energies in Table 1. The Kinchin and Pease model was used in determining the average number of displacements per primary recoil of energy T_d. Table 5 is normalized to one particle.

F. COMPARISON WITH NETURON DAMAGED DEVICES

Results obtained from electron irradiation of InP:Fe and GaAs:Cr concur with those obtained by Wagner et al. [Ref. 1] for neutron irradiated samples. This substantiative agreement holds for dark current, impulse and square-pulse response measurements. Both material types have extremely fast impulse response with differences showing up in the dark current and square-pulse responses. The GaAs:Cr samples exhibit those desirable qualities at higher fluence which include lower dark current and better accuracy in following the longer event of the square-pulse.

TABLE 5

DISPLACEMENTS

Material	In	P	Ga	As
N_o #lattice atoms/(cm^3)	2.97×10^{22}	2.97×10^{22}	4.42×10^{22}	4.42×10^{22}
Minimum Displacement Cross Section (cm^2)		3.94×10^{-22}		1.95×10^{-22}
Maximum Displacement Cross Section (cm^2)	1.49×10^{-21}		1.07×10^{-21}	
Minimum number of Displacements $(atoms/cm^3)$		11.70		43.66
Maximum number of Displacements $(atoms/cm^3)$	44.25		47.29	
Minimum number of Displacements in the sample (atoms)		.029		.109
Maximum number of Displacements in the sample (atoms)	.111		.118	
Number of Replacements $(atoms/cm^3)$	24.47	25.03	23.99	23.61

V. CONCLUSIONS

A new class of compact, reliable, sensitive and extremely high speed radiation detectors are currently being developed at the Los Alamos National Laboratory Electronics Division. They utilized neutron irradiation to introduce trapping and recombination centers into the semiconductor to speed up hole trapping for better characterization of long-event pulses. In this work, we have demonstrated that electron irradiation at 100 MeV energies is capable of qualitatively and quantitatively producing the same desirable effects.

Dark current in the GaAs:Cr devices decreases for increasing fluence whereas dark current in the InP:Fe devices increases for the same range of fluence. Impulse response controlled by carrier relaxation has been improved by electron irradiation, with response speeds < 100-ps having been achieved by both material types. Electron mobility, drift velocity and response speed have been shown to decrease with increasing fluence for both material types. In contrast to InP:Fe, the electron damaged GaAs:Cr devices show significant improvement in accurately following the longer event square-pulses by exhibiting linearity. The GaAs:Cr devices fulfill the necessary requirements for detector utilization and are expected to replace InP:Fe as the bulk-semiconductor material for many applications.

Electron irradiation from the NPS LINAC has been shown to be an alternative source for the introduction of trapping and

recombination centers resulting from irradiation damage. The LINAC provides the advantage of a well focused beam, variable energies and controlled fluence.

ITS: The Integrated TIGER Series of Coupled Electron/Photon Monte Carlo Transport Codes provides a theoretical means for characterizing an electron beam incident on detectors of various geometric shapes and sizes.

APPENDIX A

IMPULSE RESPONSE MEASUREMENT EQUIPMENT LIST

EQUIPMENT

1. Hewlett-Packard 6515A DC Power Supply
2. Hewlett-Packard 3465A Digital Multimeter
3. Ortec Detector Control Unit Model 210
4. Hamamatsu C1308 Picosec Light Pulser--

   Maximum Peak Power 10 Watts
   Wavelength 820 nm
   Repetition Rate 10 KHz

5. Newport Research Corporation Magnetic Base Model 100, 430, 360, 420
6. Tektronix 7704A Oscilloscope
7. Tektronix P7001 Processor
8. Tektronix A7704 Acquisition Unit with

   1) S-6 Sampling Head and
   2) S-53 Trigger Recognizer

9. Tektronix TDR/Sampler
10. Tektronix Amplifier
11. Tektronix Oscilloscope Camera C-27

APPENDIX B

SQUARE-PULSE RESPONSE MEASUREMENT EQUIPMENT LIST

EQUIPMENT

1. Exact Model 508A Log Sweep Function Generator

   Ramp Mode - TRIG
   Ramp Time - 100 msec
   Mode - TRIG PULSE
   Range - 100 Hz

2. Hewlett-Packard 1900A Pulse Generator

   Output 50 Ohms
   Volts into 50 Ohms
   Amplitude 2-5
   Offset 0-2
   Width 100-1K nsec
   Time Interval 10-100 micro-sec
   Rate 2.5K-25K

3. Tektronix FG 503 Function Generator

   Trigout 2.5V into 600 Ohms
   Function - Square Pulse
   Frequency - 200 Hz

4. Tektronix PG 501 Pulse Generator

   Trigout > 1V into 50 Ohms

5. Hewlett-Packard 6515A DC Power Supply

6. Hewlett-Packard 3435A Digital Multimeter

7. Keithly 177 Microvolt DMM

8. Tektronix 7104 Oscilloscope

   a) 7S11 Sampling Unit with Type S-4 Sampling
   b) 7T11 Sampling Sweep Unit
   c) 7B92A Dual Time Base
   d) Oscilloscope Camera C-27

9. Princeton Applied Research (EG+G) Model 4202 Signal Averager

10. Hewlett-Packard 7044A X-Y Recorder

11. Intronics Regulated Power Supply Model EPM 200/15TD

12. Micro Controle Newport Research Corporation

    Model B-1
    Model AC-1

APPENDIX C

INPUT PROGRAM FOR ELECTRON/PHOTON TRANSPORT ACCEPT CODE

A. CROSS SECTION

```
MATERIAL IN .788 P .212 DENSITY 4.78 SUBSTEP 40
MATERIAL GA .482 AS .518 DENSITY 5.32 SUBSTEP 40
TITLE
  100.0 MEV CROSS SECTIONS FOR PHOTOCONDUCTORS
ENERGY 100.0
```

B. MONTE CARLO

```
ECHO 1
TITLE
... 100.0 MEV KEIPPER TEST PROGRAM
*************************GEOMETRY************************
GEOMETRY 1 0
RPP 0.00 0.50 0.00 0.10 0.00 0.05
SPH 0.00 0.00 0.00 2.0
SPH 0.00 0.00 0.00 4.0
END
Z1 + 1
Z2 + 2 - 1
Z3 + 3 - 2
END
0.0025 33.5 267.9
*MAT ECUT PTCZ
1
0
0
*************************SOURCE*************************
ELECTRONS
ENERGY 100.0
POSITION 0.0 0.0 0.0
RADIUS 0.5
DIRECTION 0.0
CUTOFFS 0.05 .001
**********************OUTPUT OPTIONS********************
ELECTRON-ESCAPE
NBINE 10
PHOTON-ESCAPE
NBINE 10
ELECTRON-FLUX 1 1
NBINE 10
PHOTON-FLUX 1 1
BNINE 10
**********************OTHER OPTIONS*********************
HISTORIES 100000
```

095200

XGENPJK

USER NUMBER	095200
WORKER MACHINE	Y
DATE SENT	09 Oct 1985
TIME SENT	08:06:34
XEROX UNIT	A
PAGES DATE	9-Oct-1985
PAGES TIME	08:09:03 JOB 42651 pages1

```
ECHO
TITLE
. 100.0 MEV. KEIPPER TEST PROGRAM
*********************GEOMETRY**************************
*********
GEOMETRY 1 0
RPP 0.00 0.50 0.00 0.10 0.00 0.05
SPH 0.00 0.00 0.00 2.0
SPH 0.00 0.00 0.00 4.0
END
Z1 *+1
Z2 +2 -1
Z3 +3 -2
END
0.0025 33.5 267.9
*MAT ECUT PTCZ
1
0
0
*********************SOURCE************************
ELECTRONS
ENERGY 100.0
POSITION 0.0 0.0 0.0
RADIUS 0.5
DIRECTION 0.0
CUTOFFS 0.05 .001
*********************OUTPUT OPTIONS*****************
ELECTRON-ESCAPE
NBINE 10
PHOTON-ESCAPE
NBINE 10
ELECTRON-FLUX 1 1
NBINE 10
PHOTON-FLUX 1 1
NBINE 10
***********************OTHER OPTIONS*******************
HISTORIES 1000000
```

095200

CROSS

USER NUMBER	095200
WORKER MACHINE	Y
DATE SENT	10-Oct-1985
TIME SENT	14:28:07
XEROX UNIT	A
PAGES DATE	10-Oct-1985
PAGES TIME	14:32:29 JOB 4569[illegible] pages1

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1 ******************************************
 *                                        *
 *   PROGRAM XGEN   DECEMBER  1, 1984     *
 *            VERSION 1.0                 *
 *                                        *
 ******************************************
  END OF FILE ON UNIT 5 - XGEN

          SUMMARY OF INPUT DATA

OMAXIMUM CROSS SECTION ENERGY =    1.0000e+02
OMATERIAL 1       SOLID/LIQUID
       DENSITY            4.7800e+00
       DENSITY-RATIO    1.0000e+00
      SYMBOL  ATOMIC NUMBER   WEIGHT FRACTION
 ------------------------------------------------
   1      P          15              2.1200e-01
   2      IN         49              7.8800e-01
OMATERIAL 2       SOLID/LIQUID
       DENSITY            5.3200e+00
       DENSITY-RATIO    1.0000e+00
      SYMBOL  ATOMIC NUMBER   WEIGHT FRACTION
 ------------------------------------------------
   1      GA         31              4.8200e-01
   2      AS         33              5.1800e-01
0 ************************************************************
 *                                                          *
 *  BEGIN EXECUTING PHOTON CROSS SECTION SUBROUTINE - PGEN  *
 *                                                          *
 ************************************************************
0END OF PGEN SUBROUTINE
0*************************************************************
 *                                                           *
 * BEGIN EXECUTING ELECTRON CROSS SECTION SUBROUTINE  DATPAC *
 *                                                           *
 *************************************************************


 100.0 MEV CROSS SECTIONS FOR PHOTOCONDUCTORS
1*******************************************************
 *  ELECTRON CROSS SECTIONS FOR MATERIAL NUMBER  1  *
 *******************************************************
O ITRM  IZIP  ISGN  ISUB  INEL  ICYC  NCYC  NMAX              EMAX
    5     0     1    40     1     1     8    64      1.00000e+02
OINPUT DATA TAPE IDENTIFICATION
 DATATAPE-2 (RFSIER AIGINGER PH RAD CORR), 54 STERNHEIMER SETS  30 JAN 6
ODETOUR          DENSITY
  7.31000e-01  4.78000e+00
O
ORANGE TABLE
O      EMAX   .   NCYC       EFAC       NMAX    T(NMAX+1)   NCAL     T(NCAL)
   1.00000e+02       8   9.17004e-01     64    3.90625e-01    134   9.89410e-04
O JMAX  LMAX
    2     1
O        Z            A            W
    15.00000     30.97382      0.21200
    49.00000    114.81998      0.78800
O       PI          PID
   398.32313    398.32313
O  ----  --  ----       PARAMETERS FOR DENSITY EFFECT   -          ---
       PI             C              B             DM            X1           XO
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398.32313     5.51270     0.20987     3.00000     3.00000     0.29714
398.32313     5.51270     0.20987     3.00000     3.00000     0.29714
```

1
0 EFFECTIVE Z/A = 0.43895 EFFECTIVE MEAN IONIZATION POTENTIAL = 398.32 EV CRITICAL ENERGY = 19.388 MEV

ELECTRON RESULTS

N	ENERGY MEV	STOPPING POWER COLLISION MEV CM2/G	STOPPING POWER RADIATION MEV CM2/G	STOPPING POWER TOTAL MEV CM2/G	RANGE G/CM2	RADIATION YIELD	BETA**2	DENSITY CORR MEV CM2/G	RAD/COL	DRANGE G/CM2	DYIELD
134	9.8941e-04	3.708e+01	2.421e-02	3.710e+01	1.333e-05	0.000e+00	3.861e-03	0.000e+00	6.531e-04	1.333e-05	0.000e+00
133	1.0790e-03	3.678e+01	2.420e-02	3.680e+01	1.576e-05	5.435e-05	4.210e-03	0.000e+00	6.580e-04	2.422e-06	5.864e-08
132	1.1766e-03	3.628e+01	2.419e-02	3.630e+01	1.843e-05	1.048e-04	4.589e-03	0.000e+00	6.668e-04	2.671e-06	6.462e-08
131	1.2831e-03	3.561e+01	2.418e-02	3.563e+01	2.139e-05	1.519e-04	5.003e-03	0.000e+00	6.790e-04	2.960e-06	7.159e-08
130	1.3992e-03	3.480e+01	2.417e-02	3.483e+01	2.468e-05	1.962e-04	5.454e-03	0.000e+00	6.944e-04	3.296e-06	7.968e-08
129	1.5259e-03	3.389e+01	2.415e-02	3.391e+01	2.837e-05	2.383e-04	5.946e-03	0.000e+00	7.128e-04	3.685e-06	8.902e-08
128	1.6640e-03	3.288e+01	2.414e-02	3.291e+01	3.250e-05	2.785e-04	6.481e-03	0.000e+00	7.340e-04	4.134e-06	9.982e-08
127	1.8146e-03	3.182e+01	2.412e-02	3.184e+01	3.715e-05	3.172e-04	7.065e-03	0.000e+00	7.582e-04	4.653e-06	1.123e-07
126	1.9788e-03	3.070e+01	2.411e-02	3.073e+01	4.241e-05	3.549e-04	7.700e-03	0.000e+00	7.852e-04	5.251e-06	1.266e-07
125	2.1579e-03	2.956e+01	2.409e-02	2.958e+01	4.835e-05	3.918e-04	8.393e-03	0.000e+00	8.151e-04	5.941e-06	1.432e-07
124	2.3532e-03	2.839e+01	2.408e-02	2.842e+01	5.508e-05	4.282e-04	9.147e-03	0.000e+00	8.480e-04	6.737e-06	1.623e-07
123	2.5662e-03	2.722e+01	2.406e-02	2.725e+01	6.274e-05	4.645e-04	9.969e-03	0.000e+00	8.839e-04	7.656e-06	1.843e-07
122	2.7985e-03	2.605e+01	2.404e-02	2.607e+01	7.146e-05	5.009e-04	1.086e-02	0.000e+00	9.229e-04	8.716e-06	2.096e-07
121	3.0518e-03	2.489e+01	2.402e-02	2.491e+01	8.140e-05	5.376e-04	1.184e-02	0.000e+00	9.653e-04	9.941e-06	2.389e-07
120	3.3280e-03	2.374e+01	2.401e-02	2.377e+01	9.275e-05	5.749e-04	1.290e-02	0.000e+00	1.011e-03	1.135e-05	2.727e-07
119	3.6292e-03	2.262e+01	2.399e-02	2.264e+01	1.057e-04	6.131e-04	1.405e-02	0.000e+00	1.061e-03	1.299e-05	3.117e-07
118	3.9576e-03	2.152e+01	2.397e-02	2.154e+01	1.206e-04	6.523e-04	1.531e-02	0.000e+00	1.114e-03	1.488e-05	3.567e-07
117	4.3158e-03	2.045e+01	2.395e-02	2.047e+01	1.377e-04	6.929e-04	1.668e-02	0.000e+00	1.171e-03	1.706e-05	4.087e-07
116	4.7065e-03	1.941e+01	2.393e-02	1.944e+01	1.573e-04	7.350e-04	1.817e-02	0.000e+00	1.232e-03	1.959e-05	4.689e-07
115	5.1324e-03	1.841e+01	2.391e-02	1.843e+01	1.798e-04	7.789e-04	1.979e-02	0.000e+00	1.298e-03	2.251e-05	5.384e-07
114	5.5969e-03	1.744e+01	2.388e-02	1.747e+01	2.057e-04	8.248e-04	2.155e-02	0.000e+00	1.369e-03	2.590e-05	6.188e-07
113	6.1035e-03	1.651e+01	2.386e-02	1.654e+01	2.355e-04	8.730e-04	2.347e-02	0.000e+00	1.445e-03	2.982e-05	7.119e-07
112	6.6559e-03	1.562e+01	2.384e-02	1.564e+01	2.699e-04	9.237e-04	2.555e-02	0.000e+00	1.526e-03	3.436e-05	8.196e-07
111	7.2583e-03	1.476e+01	2.382e-02	1.479e+01	3.095e-04	9.771e-04	2.782e-02	0.000e+00	1.613e-03	3.963e-05	9.442e-07
110	7.9153e-03	1.395e+01	2.380e-02	1.397e+01	3.552e-04	1.034e-03	3.028e-02	0.000e+00	1.706e-03	4.573e-05	1.089e-06
109	8.6317e-03	1.317e+01	2.377e-02	1.319e+01	4.080e-04	1.093e-03	3.295e-02	0.000e+00	1.806e-03	5.280e-05	1.256e-06
108	9.4129e-03	1.242e+01	2.375e-02	1.245e+01	4.690e-04	1.157e-03	3.585e-02	0.000e+00	1.912e-03	6.101e-05	1.450e-06
107	1.0265e-02	1.171e+01	2.373e-02	1.174e+01	5.395e-04	1.224e-03	3.900e-02	0.000e+00	2.025e-03	7.052e-05	1.674e-06
106	1.1194e-02	1.104e+01	2.371e-02	1.107e+01	6.211e-04	1.295e-03	4.241e-02	0.000e+00	2.147e-03	8.156e-05	1.934e-06
105	1.2207e-02	1.041e+01	2.369e-02	1.043e+01	7.155e-04	1.371e-03	4.612e-02	0.000e+00	2.276e-03	9.436e-05	2.236e-06
104	1.3312e-02	9.801e+00	2.367e-02	9.824e+00	8.247e-04	1.451e-03	5.014e-02	0.000e+00	2.415e-03	1.092e-04	2.586e-06
103	1.4517e-02	9.229e+00	2.365e-02	9.252e+00	9.511e-04	1.537e-03	5.449e-02	0.000e+00	2.562e-03	1.264e-04	2.991e-06
102	1.5831e-02	8.688e+00	2.363e-02	8.712e+00	1.098e-03	1.628e-03	5.920e-02	0.000e+00	2.720e-03	1.464e-04	3.461e-06
101	1.7263e-02	8.177e+00	2.361e-02	8.201e+00	1.267e-03	1.725e-03	6.429e-02	0.000e+00	2.888e-03	1.696e-04	4.006e-06
100	1.8826e-02	7.695e+00	2.360e-02	7.719e+00	1.464e-03	1.828e-03	6.980e-02	0.000e+00	3.066e-03	1.965e-04	4.638e-06
99	2.0530e-02	7.241e+00	2.359e-02	7.265e+00	1.691e-03	1.938e-03	7.576e-02	0.000e+00	3.257e-03	2.277e-04	5.371e-06
98	2.2388e-02	6.813e+00	2.358e-02	6.837e+00	1.955e-03	2.055e-03	8.219e-02	0.000e+00	3.461e-03	2.638e-04	6.222e-06
97	2.4414e-02	6.411e+00	2.358e-02	6.434e+00	2.261e-03	2.180e-03	8.912e-02	0.000e+00	3.678e-03	3.057e-04	7.208e-06
96	2.6624e-02	6.032e+00	2.358e-02	6.056e+00	2.615e-03	2.312e-03	9.659e-02	0.000e+00	3.910e-03	3.542e-04	8.352e-06
95	2.9033e-02	5.677e+00	2.359e-02	5.700e+00	3.025e-03	2.454e-03	1.046e-01	0.000e+00	4.156e-03	4.104e-04	9.680e-06
94	3.1661e-02	5.343e+00	2.361e-02	5.366e+00	3.501e-03	2.605e-03	1.133e-01	0.000e+00	4.419e-03	4.754e-04	1.122e-05
93	3.4527e-02	5.030e+00	2.363e-02	5.053e+00	4.051e-03	2.765e-03	1.226e-01	0.000e+00	4.698e-03	5.506e-04	1.300e-05
92	3.7652e-02	4.736e+00	2.367e-02	4.760e+00	4.689e-03	2.936e-03	1.325e-01	0.000e+00	4.996e-03	6.375e-04	1.508e-05
91	4.1059e-02	4.462e+00	2.371e-02	4.485e+00	5.427e-03	3.118e-03	1.432e-01	0.000e+00	5.314e-03	7.379e-04	1.748e-05
90	4.4776e-02	4.205e+00	2.377e-02	4.228e+00	6.281e-03	3.312e-03	1.546e-01	0.000e+00	5.654e-03	8.538e-04	2.027e-05
89	4.8828e-02	3.964e+00	2.384e-02	3.988e+00	7.268e-03	3.519e-03	1.668e-01	0.000e+00	6.014e-03	9.874e-04	2.351e-05
88	5.3247e-02	3.740e+00	2.393e-02	3.764e+00	8.410e-03	3.739e-03	1.798e-01	0.000e+00	6.398e-03	1.141e-03	2.726e-05
87	5.8067e-02	3.530e+00	2.402e-02	3.554e+00	9.728e-03	3.973e-03	1.937e-01	0.000e+00	6.804e-03	1.318e-03	3.161e-05
86	6.3322e-02	3.335e+00	2.413e-02	3.359e+00	1.125e-02	4.222e-03	2.084e-01	0.000e+00	7.237e-03	1.522e-03	3.664e-05
85	6.9053e-02	3.152e+00	2.426e-02	3.177e+00	1.301e-02	4.486e-03	2.239e-01	0.000e+00	7.696e-03	1.756e-03	4.248e-05
84	7.5303e-02	2.983e+00	2.441e-02	3.007e+00	1.503e-02	4.768e-03	2.404e-01	0.000e+00	8.185e-03	2.023e-03	4.924e-05
83	8.2119e-02	2.825e+00	2.458e-02	2.849e+00	1.736e-02	5.067e-03	2.577e-01	0.000e+00	8.700e-03	2.310e-03	5.707e-05
82	8.9551e-02	2.678e+00	2.476e-02	2.703e+00	2.004e-02	5.385e-03	2.760e-01	0.000e+00	9.245e-03	2.680e-03	6.611e-05
81	9.7656e-02	2.542e+00	2.496e-02	2.567e+00	2.312e-02	5.722e-03	2.952e-01	0.000e+00	9.821e-03	3.079e-03	7.655e-05
80	1.0649e-01	2.415e+00	2.520e-02	2.441e+00	2.665e-02	6.079e-03	3.152e-01	0.000e+00	1.043e-02	3.531e-03	8.862e-05
79	1.1613e-01	2.298e+00	2.546e-02	2.324e+00	3.070e-02	6.458e-03	3.361e-01	0.000e+00	1.108e-02	4.050e-03	1.026e-04

78	1.2664e-01	2.190e+00	2.575e-02	2.216e+00	3.534e-02	6.859e-03	3.578e-01	0.000e+00	1.176e-02	4.635e-03	1.187e-04
77	1.3811e-01	2.090e+00	2.608e-02	2.116e+00	4.063e-02	7.284e-03	3.803e-01	0.000e+00	1.248e-02	5.297e-03	1.373e-04
76	1.5061e-01	1.997e+00	2.646e-02	2.024e+00	4.668e-02	7.733e-03	4.035e-01	0.000e+00	1.325e-02	6.044e-03	1.588e-04
75	1.6424e-01	1.912e+00	2.688e-02	1.939e+00	5.356e-02	8.210e-03	4.273e-01	0.000e+00	1.406e-02	6.884e-03	1.836e-04
74	1.7910e-01	1.834e+00	2.734e-02	1.861e+00	6.139e-02	8.713e-03	4.517e-01	0.000e+00	1.491e-02	7.828e-03	2.122e-04
73	1.9531e-01	1.762e+00	2.787e-02	1.790e+00	7.027e-02	9.246e-03	4.766e-01	0.000e+00	1.582e-02	8.885e-03	2.453e-04
72	2.1299e-01	1.697e+00	2.848e-02	1.725e+00	8.034e-02	9.810e-03	5.018e-01	0.000e+00	1.679e-02	1.006e-02	2.836e-04
71	2.3227e-01	1.637e+00	2.916e-02	1.666e+00	9.172e-02	1.041e-02	5.274e-01	0.000e+00	1.782e-02	1.138e-02	3.279e-04
70	2.5329e-01	1.582e+00	2.991e-02	1.612e+00	1.046e-01	1.104e-02	5.530e-01	0.000e+00	1.891e-02	1.284e-02	3.791e-04
69	2.7621e-01	1.532e+00	3.076e-02	1.563e+00	1.190e-01	1.171e-02	5.787e-01	0.000e+00	2.008e-02	1.445e-02	4.384e-04
68	3.0121e-01	1.487e+00	3.172e-02	1.519e+00	1.352e-01	1.242e-02	6.042e-01	0.000e+00	2.133e-02	1.623e-02	5.071e-04
67	3.2848e-01	1.447e+00	3.281e-02	1.480e+00	1.534e-01	1.318e-02	6.295e-01	0.000e+00	2.267e-02	1.819e-02	5.869e-04
66	3.5820e-01	1.411e+00	3.401e-02	1.445e+00	1.738e-01	1.398e-02	6.544e-01	0.000e+00	2.410e-02	2.034e-02	6.795e-04
65	3.9063e-01	1.379e+00	3.533e-02	1.414e+00	1.964e-01	1.483e-02	6.788e-01	0.000e+00	2.562e-02	2.269e-02	7.866e-04
64	4.2598e-01	1.350e+00	3.677e-02	1.387e+00	2.217e-01	1.574e-02	7.026e-01	0.000e+00	2.723e-02	2.525e-02	9.107e-04
63	4.6453e-01	1.325e+00	3.838e-02	1.364e+00	2.497e-01	1.670e-02	7.256e-01	0.000e+00	2.896e-02	2.804e-02	1.054e-03
62	5.0658e-01	1.304e+00	4.019e-02	1.344e+00	2.808e-01	1.773e-02	7.478e-01	0.000e+00	3.083e-02	3.107e-02	1.220e-03
61	5.5243e-01	1.285e+00	4.223e-02	1.327e+00	3.152e-01	1.882e-02	7.691e-01	0.000e+00	3.286e-02	3.434e-02	1.415e-03
60	6.0243e-01	1.269e+00	4.451e-02	1.314e+00	3.530e-01	1.998e-02	7.894e-01	0.000e+00	3.506e-02	3.787e-02	1.643e-03
59	6.5695e-01	1.256e+00	4.703e-02	1.303e+00	3.947e-01	2.123e-02	8.086e-01	4.340e-05	3.743e-02	4.167e-02	1.907e-03
58	7.1641e-01	1.246e+00	4.989e-02	1.296e+00	4.405e-01	2.256e-02	8.267e-01	2.666e-04	4.005e-02	4.576e-02	2.216e-03
57	7.8125e-01	1.237e+00	5.294e-02	1.290e+00	4.906e-01	2.399e-02	8.436e-01	6.746e-04	4.278e-02	5.016e-02	2.579e-03
56	8.5196e-01	1.231e+00	5.624e-02	1.287e+00	5.455e-01	2.551e-02	8.594e-01	1.265e-03	4.568e-02	5.487e-02	2.995e-03
55	9.2907e-01	1.227e+00	5.983e-02	1.286e+00	6.054e-01	2.714e-02	8.741e-01	2.036e-03	4.878e-02	5.993e-02	3.478e-03
54	1.0132e+00	1.224e+00	6.377e-02	1.288e+00	6.708e-01	2.887e-02	8.876e-01	2.988e-03	5.210e-02	6.535e-02	4.036e-03
53	1.1049e+00	1.223e+00	6.833e-02	1.291e+00	7.419e-01	3.072e-02	9.000e-01	4.123e-03	5.589e-02	7.113e-02	4.697e-03
52	1.2049e+00	1.223e+00	7.349e-02	1.297e+00	8.192e-01	3.272e-02	9.113e-01	5.444e-03	6.008e-02	7.729e-02	5.480e-03
51	1.3139e+00	1.225e+00	7.952e-02	1.304e+00	9.030e-01	3.489e-02	9.216e-01	6.953e-03	6.492e-02	8.386e-02	6.415e-03
50	1.4328e+00	1.228e+00	8.596e-02	1.314e+00	9.939e-01	3.724e-02	9.309e-01	8.655e-03	7.001e-02	9.085e-02	7.516e-03
49	1.5625e+00	1.232e+00	9.311e-02	1.325e+00	1.092e+00	3.978e-02	9.393e-01	1.055e-02	7.559e-02	9.830e-02	8.800e-03
48	1.7039e+00	1.237e+00	1.011e-01	1.338e+00	1.198e+00	4.253e-02	9.468e-01	1.265e-02	8.171e-02	1.062e-01	1.031e-02
47	1.8581e+00	1.243e+00	1.098e-01	1.353e+00	1.313e+00	4.550e-02	9.535e-01	1.496e-02	8.838e-02	1.146e-01	1.208e-02
46	2.0263e+00	1.250e+00	1.197e-01	1.369e+00	1.437e+00	4.872e-02	9.594e-01	1.747e-02	9.582e-02	1.236e-01	1.418e-02
45	2.2097e+00	1.257e+00	1.308e-01	1.388e+00	1.570e+00	5.222e-02	9.647e-01	2.020e-02	1.040e-01	1.330e-01	1.666e-02
44	2.4097e+00	1.265e+00	1.431e-01	1.408e+00	1.713e+00	5.602e-02	9.694e-01	2.315e-02	1.132e-01	1.431e-01	1.959e-02
43	2.6278e+00	1.273e+00	1.570e-01	1.430e+00	1.866e+00	6.014e-02	9.735e-01	2.632e-02	1.233e-01	1.537e-01	2.306e-02
42	2.8656e+00	1.282e+00	1.724e-01	1.455e+00	2.031e+00	6.462e-02	9.771e-01	2.971e-02	1.345e-01	1.649e-01	2.715e-02
41	3.1250e+00	1.292e+00	1.896e-01	1.481e+00	2.208e+00	6.949e-02	9.803e-01	3.333e-02	1.468e-01	1.767e-01	3.197e-02
40	3.4078e+00	1.301e+00	2.091e-01	1.510e+00	2.397e+00	7.478e-02	9.830e-01	3.718e-02	1.606e-01	1.891e-01	3.769e-02
39	3.7163e+00	1.311e+00	2.305e-01	1.542e+00	2.599e+00	8.052e-02	9.854e-01	4.126e-02	1.758e-01	2.021e-01	4.440e-02
38	4.0526e+00	1.321e+00	2.542e-01	1.576e+00	2.815e+00	8.674e-02	9.875e-01	4.557e-02	1.924e-01	2.158e-01	5.228e-02
37	4.4194e+00	1.332e+00	2.805e-01	1.612e+00	3.045e+00	9.346e-02	9.893e-01	5.012e-02	2.107e-01	2.301e-01	6.151e-02
36	4.8194e+00	1.342e+00	3.096e-01	1.652e+00	3.290e+00	1.007e-01	9.908e-01	5.489e-02	2.307e-01	2.451e-01	7.231e-02
35	5.2556e+00	1.352e+00	3.418e-01	1.694e+00	3.551e+00	1.085e-01	9.921e-01	5.990e-02	2.527e-01	2.607e-01	8.490e-02
34	5.7313e+00	1.363e+00	3.774e-01	1.740e+00	3.828e+00	1.169e-01	9.933e-01	6.514e-02	2.769e-01	2.770e-01	9.958e-02
33	6.2500e+00	1.373e+00	4.166e-01	1.790e+00	4.122e+00	1.258e-01	9.943e-01	7.061e-02	3.034e-01	2.939e-01	1.166e-01
32	6.8157e+00	1.384e+00	4.599e-01	1.844e+00	4.433e+00	1.354e-01	9.951e-01	7.631e-02	3.324e-01	3.114e-01	1.364e-01
31	7.4325e+00	1.394e+00	5.077e-01	1.902e+00	4.763e+00	1.456e-01	9.959e-01	8.224e-02	3.642e-01	3.294e-01	1.593e-01
30	8.1052e+00	1.404e+00	5.604e-01	1.965e+00	5.111e+00	1.564e-01	9.965e-01	8.838e-02	3.990e-01	3.480e-01	1.858e-01
29	8.8388e+00	1.415e+00	6.185e-01	2.033e+00	5.478e+00	1.679e-01	9.970e-01	9.475e-02	4.372e-01	3.670e-01	2.163e-01
28	9.6388e+00	1.425e+00	6.826e-01	2.107e+00	5.864e+00	1.801e-01	9.975e-01	1.013e-01	4.791e-01	3.864e-01	2.513e-01
27	1.0511e+01	1.435e+00	7.532e-01	2.188e+00	6.270e+00	1.928e-01	9.979e-01	1.081e-01	5.249e-01	4.062e-01	2.915e-01
26	1.1463e+01	1.445e+00	8.310e-01	2.276e+00	6.696e+00	2.063e-01	9.982e-01	1.151e-01	5.752e-01	4.263e-01	3.375e-01
25	1.2500e+01	1.455e+00	9.167e-01	2.371e+00	7.143e+00	2.204e-01	9.985e-01	1.224e-01	6.302e-01	4.466e-01	3.901e-01
24	1.3631e+01	1.464e+00	1.011e+00	2.476e+00	7.610e+00	2.351e-01	9.987e-01	1.298e-01	6.907e-01	4.669e-01	4.499e-01
23	1.4865e+01	1.474e+00	1.115e+00	2.589e+00	8.097e+00	2.504e-01	9.989e-01	1.374e-01	7.567e-01	4.873e-01	5.179e-01
22	1.6210e+01	1.481e+00	1.229e+00	2.712e+00	8.605e+00	2.663e-01	9.991e-01	1.452e-01	8.288e-01	5.077e-01	5.948e-01
21	1.7678e+01	1.492e+00	1.355e+00	2.847e+00	9.133e+00	2.828e-01	9.992e-01	1.532e-01	9.077e-01	5.279e-01	6.817e-01
20	1.9278e+01	1.501e+00	1.492e+00	2.994e+00	9.681e+00	2.998e-01	9.993e-01	1.614e-01	9.940e-01	5.480e-01	7.797e-01
19	2.1022e+01	1.510e+00	1.644e+00	3.154e+00	1.025e+01	3.172e-01	9.994e-01	1.697e-01	1.088e+00	5.677e-01	8.898e-01
18	2.2925e+01	1.519e+00	1.810e+00	3.329e+00	1.084e+01	3.351e-01	9.995e-01	1.783e-01	1.192e+00	5.871e-01	1.013e+00
17	2.5000e+01	1.528e+00	1.993e+00	3.521e+00	1.144e+01	3.533e-01	9.996e-01	1.870e-01	1.304e+00	6.060e-01	1.152e+00
16	2.7263e+01	1.536e+00	2.193e+00	3.729e+00	1.207e+01	3.719e-01	9.997e-01	1.959e-01	1.428e+00	6.244e-01	1.306e+00
15	2.9730e+01	1.545e+00	2.413e+00	3.957e+00	1.271e+01	3.908e-01	9.997e-01	2.049e-01	1.562e+00	6.422e-01	1.478e+00

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 14  3.2421e+01   1.553e+00 2.654e+00 4.207e+00 1.337e+01 4.098e-01   9.998e-01 2.141e-01 1.709e+00 6.594e-01 1.670e+00
 13  3.5355e+01   1.561e+00 2.918e+00 4.479e+00 1.404e+01 4.291e-01   9.998e-01 2.234e-01 1.869e+00 6.759e-01 1.882e+00
 12  3.8555e+01   1.569e+00 3.207e+00 4.776e+00 1.474e+01 4.484e-01   9.998e-01 2.329e-01 2.044e+00 6.918e-01 2.117e+00
 11  4.2045e+01   1.577e+00 3.524e+00 5.101e+00 1.544e+01 4.677e-01   9.999e-01 2.426e-01 2.235e+00 7.069e-01 2.378e+00
 10  4.5850e+01   1.584e+00 3.871e+00 5.456e+00 1.616e+01 4.870e-01   9.999e-01 2.523e-01 2.444e+00 7.212e-01 2.665e+00
  9  5.0000e+01   1.592e+00 4.252e+00 5.844e+00 1.690e+01 5.063e-01   9.999e-01 2.622e-01 2.671e+00 7.348e-01 2.983e+00
  8  5.4525e+01   1.599e+00 4.668e+00 6.268e+00 1.765e+01 5.254e-01   9.999e-01 2.723e-01 2.913e+00 7.476e-01 3.332e+00
  7  5.9460e+01   1.607e+00 5.125e+00 6.731e+00 1.841e+01 5.443e-01   9.999e-01 2.824e-01 3.190e+00 7.596e-01 3.717e+00
  6  6.4842e+01   1.614e+00 5.624e+00 7.238e+00 1.918e+01 5.630e-01   9.999e-01 2.927e-01 3.484e+00 7.709e-01 4.140e+00
  5  7.0711e+01   1.621e+00 6.169e+00 7.790e+00 1.996e+01 5.813e-01   9.999e-01 3.031e-01 3.806e+00 7.814e-01 4.605e+00
  4  7.7111e+01   1.628e+00 6.766e+00 8.394e+00 2.075e+01 5.994e-01   1.000e+00 3.136e-01 4.156e+00 7.913e-01 5.114e+00
  3  8.4090e+01   1.635e+00 7.418e+00 9.053e+00 2.155e+01 6.171e-01   1.000e+00 3.241e-01 4.537e+00 8.004e-01 5.673e+00
  2  9.1700e+01   1.642e+00 8.131e+00 9.773e+00 2.236e+01 6.345e-01   1.000e+00 3.348e-01 4.953e+00 8.089e-01 6.285e+00
  1  1.0000e+02   1.648e+00 8.910e+00 1.056e+01 2.318e+01 6.514e-01   1.000e+00 3.456e-01 5.405e+00 8.169e-01 6.956e+00
1*****************************************************
 *  ELECTRON CROSS SECTIONS FOR MATERIAL NUMBER  2  *
 *****************************************************
O ITRM  IZIP  ISGN  ISUB  INEL  ICYC  NCYC  NMAX              EMAX
    5     0     1    40     1     1     8    64       1.00000e+02
OINPUT DATA TAPE IDENTIFICATION
 DATATAPE-2 (RESTER AIGINGER PH RAD CORR), 54 STERNHEIMER SETS  30 JAN 6
ODETOUR          DENSITY
  3.95000e-01  5.32000e+00
O
ORANGE TABLE
O      EMAX        NCYC       EFAC        NMAX    T(NMAX+1)    NCAL      T(NCAL)
   1.00000e+02       8    9.17004e-01     64    3.90625e-01    134    9.89410e-04
O JMAX  LMAX
    2     1
O        Z           A            W
    31.00000    69.71995     0.48200
    33.00000    74.92167     0.51800
O       PI          PID
   342.92607   342.92607
O  -------------------- PARAMETERS FOR DENSITY EFFECT- -------------------
        PI            C            B            DM           X1           XO

   342.92607    -5.09818      0.19028      3.00000      3.00000      0.20000
   342.92607    -5.09818      0.19028      3.00000      3.00000      0.20000
1                                                        ELECTRON RESULTS
O     EFFECTIVE Z/A = 0.44247      EFFECTIVE MEAN IONIZATION POTENTIAL =  342.93 EV     CRITICAL ENERGY =  23.396 MEV
O         ENERGY             STOPPING POWER              RANGE    RADIATION   BETA**2   DENSITY   RAD/COL    ORANGE      DYIELD
    N                  COLLISION RADIATION   TOTAL                  YIELD                 CORR
          MEV          MEV CM2/G MEV CM2/G MEV CM2/G   G/CM2                           MEV CM2/G             G/CM2

  134  9.8941e-04   4.265e+01 1.918e-02 4.267e+01 1.159e-05 0.000e+00   3.861e-03 0.000e+00 4.497e-04 1.159e-05 0.000e+00
  133  1.0790e-03   4.191e+01 1.917e-02 4.193e+01 1.371e-05 3.761e-05   4.210e-03 0.000e+00 4.574e-04 2.117e-06 4.058e-08
  132  1.1766e-03   4.100e+01 1.916e-02 4.102e+01 1.607e-05 7.284e-05   4.589e-03 0.000e+00 4.673e-04 2.354e-06 4.512e-08
  131  1.2831e-03   3.996e+01 1.915e-02 3.998e+01 1.870e-05 1.060e-04   5.003e-03 0.000e+00 4.792e-04 2.629e-06 5.037e-08
  130  1.3992e-03   3.881e+01 1.914e-02 3.883e+01 2.164e-05 1.376e-04   5.454e-03 0.000e+00 4.932e-04 2.947e-06 5.643e-08
  129  1.5259e-03   3.758e+01 1.913e-02 3.760e+01 2.496e-05 1.677e-04   5.946e-03 0.000e+00 5.091e-04 3.314e-06 6.342e-08
  128  1.6640e-03   3.629e+01 1.912e-02 3.631e+01 2.869e-05 1.968e-04   6.481e-03 0.000e+00 5.269e-04 3.738e-06 7.149e-08
  127  1.8146e-03   3.495e+01 1.911e-02 3.497e+01 3.292e-05 2.250e-04   7.065e-03 0.000e+00 5.467e-04 4.227e-06 8.080e-08
  126  1.9788e-03   3.359e+01 1.910e-02 3.361e+01 3.771e-05 2.525e-04   7.700e-03 0.000e+00 5.685e-04 4.791e-06 9.153e-08
  125  2.1579e-03   3.222e+01 1.909e-02 3.224e+01 4.315e-05 2.797e-04   8.393e-03 0.000e+00 5.924e-04 5.442e-06 1.039e-07
  124  2.3532e-03   3.085e+01 1.907e-02 3.087e+01 4.935e-05 3.067e-04   9.147e-03 0.000e+00 6.184e-04 6.193e-06 1.182e-07
  123  2.5662e-03   2.948e+01 1.906e-02 2.950e+01 5.641e-05 3.337e-04   9.969e-03 0.000e+00 6.466e-04 7.060e-06 1.346e-07
  122  2.7985e-03   2.813e+01 1.905e-02 2.815e+01 6.447e-05 3.609e-04   1.086e-02 0.000e+00 6.772e-04 8.062e-06 1.536e-07
  121  3.0518e-03   2.681e+01 1.904e-02 2.683e+01 7.369e-05 3.885e-04   1.184e-02 0.000e+00 7.101e-04 9.220e-06 1.756e-07
  120  3.3280e-03   2.551e+01 1.902e-02 2.553e+01 8.425e-05 4.166e-04   1.290e-02 0.000e+00 7.457e-04 1.056e-05 2.009e-07
  119  3.6292e-03   2.425e+01 1.901e-02 2.427e+01 9.635e-05 4.455e-04   1.405e-02 0.000e+00 7.840e-04 1.211e-05 2.302e-07
  118  3.9576e-03   2.302e+01 1.900e-02 2.304e+01 1.102e-04 4.752e-04   1.531e-02 0.000e+00 8.252e-04 1.390e-05 2.641e-07
  117  4.3158e-03   2.183e+01 1.898e-02 2.185e+01 1.262e-04 5.061e-04   1.668e-02 0.000e+00 8.694e-04 1.597e-05 3.033e-07
  116  4.7065e-03   2.069e+01 1.897e-02 2.071e+01 1.446e-04 5.381e-04   1.817e-02 0.000e+00 9.169e-04 1.837e-05 3.486e-07
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AD-A164 413 INP:FE AND GAAS:CR PICOSECOND PHOTOCONDUCTIVE RADIATION 2/2
DETECTORS(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA
P J KEIPPER DEC 85

UNCLASSIFIED F/G 18/4 NL

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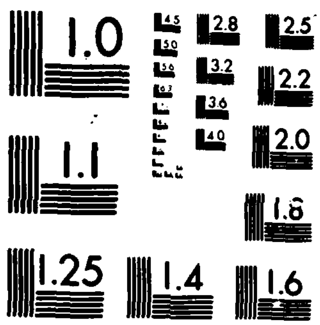

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

115	5.1321e-03	1.959e+01	1.896e-02	1.961e+01	1.657e-04	5.716e-04	1.979e-02	0.000e+00	9.678e-04	2.115e-05	4.010e-07
114	5.5963e-03	1.851e+01	1.894e-02	1.855e+01	1.901e-04	6.067e-04	2.155e-02	0.000e+00	1.022e-03	2.417e-05	4.618e-07
113	6.1035e-03	1.751e+01	1.893e-02	1.753e+01	2.182e-04	6.435e-04	2.347e-02	0.000e+00	1.081e-03	2.811e-05	5.322e-07
112	6.6559e-03	1.654e+01	1.891e-02	1.656e+01	2.507e-04	6.823e-04	2.555e-02	0.000e+00	1.143e-03	3.244e-05	6.137e-07
111	7.2583e-03	1.561e+01	1.890e-02	1.563e+01	2.881e-04	7.232e-04	2.782e-02	0.000e+00	1.210e-03	3.746e-05	7.082e-07
110	7.9153e-03	1.473e+01	1.888e-02	1.475e+01	3.314e-04	7.665e-04	3.028e-02	0.000e+00	1.282e-03	4.328e-05	8.177e-07
109	8.6317e-03	1.389e+01	1.887e-02	1.391e+01	3.814e-04	8.123e-04	3.295e-02	0.000e+00	1.359e-03	5.004e-05	9.447e-07
108	9.4129e-03	1.309e+01	1.886e-02	1.311e+01	4.393e-04	8.609e-04	3.585e-02	0.000e+00	1.441e-03	5.789e-05	1.092e-06
107	1.0265e-02	1.231e+01	1.884e-02	1.235e+01	5.063e-04	9.125e-04	3.900e-02	0.000e+00	1.528e-03	6.699e-05	1.263e-06
106	1.1194e-02	1.161e+01	1.883e-02	1.163e+01	5.839e-04	9.673e-04	4.241e-02	0.000e+00	1.622e-03	7.756e-05	1.461e-06
105	1.2207e-02	1.093e+01	1.882e-02	1.095e+01	6.737e-04	1.026e-03	4.612e-02	0.000e+00	1.721e-03	8.983e-05	1.691e-06
104	1.3312e-02	1.029e+01	1.881e-02	1.030e+01	7.778e-04	1.087e-03	5.014e-02	0.000e+00	1.828e-03	1.041e-04	1.958e-06
103	1.4517e-02	9.676e+00	1.879e-02	9.695e+00	8.984e-04	1.153e-03	5.449e-02	0.000e+00	1.942e-03	1.206e-04	2.267e-06
102	1.5831e-02	9.102e+00	1.878e-02	9.120e+00	1.038e-03	1.224e-03	5.920e-02	0.000e+00	2.063e-03	1.398e-04	2.626e-06
101	1.7263e-02	8.559e+00	1.877e-02	8.578e+00	1.200e-03	1.298e-03	6.429e-02	0.000e+00	2.192e-03	1.621e-04	3.043e-06
100	1.8826e-02	8.049e+00	1.875e-02	8.067e+00	1.388e-03	1.378e-03	6.980e-02	0.000e+00	2.330e-03	1.879e-04	3.526e-06
99	2.0530e-02	7.568e+00	1.874e-02	7.587e+00	1.606e-03	1.462e-03	7.576e-02	0.000e+00	2.477e-03	2.179e-04	4.086e-06
98	2.2388e-02	7.116e+00	1.873e-02	7.134e+00	1.859e-03	1.553e-03	8.219e-02	0.000e+00	2.633e-03	2.527e-04	4.735e-06
97	2.4414e-02	6.690e+00	1.873e-02	6.709e+00	2.152e-03	1.649e-03	8.912e-02	0.000e+00	2.799e-03	2.931e-04	5.489e-06
96	2.6624e-02	6.291e+00	1.872e-02	6.310e+00	2.492e-03	1.751e-03	9.659e-02	0.000e+00	2.976e-03	3.398e-04	6.362e-06
95	2.9033e-02	5.917e+00	1.872e-02	5.935e+00	2.886e-03	1.859e-03	1.046e-01	0.000e+00	3.164e-03	3.940e-04	7.375e-06
94	3.1661e-02	5.565e+00	1.872e-02	5.584e+00	3.342e-03	1.975e-03	1.133e-01	0.000e+00	3.363e-03	4.567e-04	8.548e-06
93	3.4527e-02	5.236e+00	1.872e-02	5.255e+00	3.872e-03	2.098e-03	1.226e-01	0.000e+00	3.575e-03	5.293e-04	9.907e-06
92	3.7652e-02	4.928e+00	1.873e-02	4.947e+00	4.485e-03	2.229e-03	1.325e-01	0.000e+00	3.800e-03	6.133e-04	1.148e-05
91	4.1059e-02	4.640e+00	1.874e-02	4.658e+00	5.195e-03	2.368e-03	1.432e-01	0.000e+00	4.039e-03	7.103e-04	1.331e-05
90	4.4776e-02	4.370e+00	1.876e-02	4.389e+00	6.018e-03	2.516e-03	1.546e-01	0.000e+00	4.293e-03	8.224e-04	1.542e-05
89	4.8828e-02	4.118e+00	1.879e-02	4.137e+00	6.969e-03	2.673e-03	1.668e-01	0.000e+00	4.562e-03	9.517e-04	1.787e-05
88	5.3247e-02	3.883e+00	1.882e-02	3.902e+00	8.070e-03	2.840e-03	1.798e-01	0.000e+00	4.847e-03	1.101e-03	2.070e-05
87	5.8067e-02	3.664e+00	1.886e-02	3.682e+00	9.342e-03	3.017e-03	1.937e-01	0.000e+00	5.148e-03	1.272e-03	2.397e-05
86	6.3322e-02	3.459e+00	1.891e-02	3.478e+00	1.081e-02	3.205e-03	2.084e-01	0.000e+00	5.468e-03	1.469e-03	2.775e-05
85	6.9053e-02	3.269e+00	1.898e-02	3.288e+00	1.251e-02	3.404e-03	2.239e-01	0.000e+00	5.806e-03	1.696e-03	3.213e-05
84	7.5303e-02	3.091e+00	1.905e-02	3.110e+00	1.446e-02	3.615e-03	2.404e-01	0.000e+00	6.163e-03	1.956e-03	3.719e-05
83	8.2119e-02	2.926e+00	1.914e-02	2.946e+00	1.672e-02	3.839e-03	2.577e-01	0.000e+00	6.540e-03	2.253e-03	4.302e-05
82	8.9551e-02	2.773e+00	1.924e-02	2.792e+00	1.931e-02	4.076e-03	2.760e-01	0.000e+00	6.938e-03	2.593e-03	4.976e-05
81	9.7656e-02	2.631e+00	1.936e-02	2.650e+00	2.229e-02	4.327e-03	2.952e-01	0.000e+00	7.357e-03	2.981e-03	5.753e-05
80	1.0649e-01	2.499e+00	1.950e-02	2.519e+00	2.571e-02	4.592e-03	3.152e-01	0.000e+00	7.801e-03	3.423e-03	6.650e-05
79	1.1613e-01	2.377e+00	1.966e-02	2.397e+00	2.964e-02	4.873e-03	3.361e-01	0.000e+00	8.271e-03	3.925e-03	7.685e-05
78	1.2664e-01	2.264e+00	1.984e-02	2.284e+00	3.413e-02	5.170e-03	3.578e-01	0.000e+00	8.762e-03	4.495e-03	8.880e-05
77	1.3811e-01	2.160e+00	2.006e-02	2.180e+00	3.927e-02	5.483e-03	3.803e-01	0.000e+00	9.286e-03	5.139e-03	1.025e-04
76	1.5061e-01	2.064e+00	2.031e-02	2.084e+00	4.514e-02	5.814e-03	4.035e-01	0.000e+00	9.841e-03	5.867e-03	1.184e-04
75	1.6424e-01	1.975e+00	2.060e-02	1.996e+00	5.181e-02	6.165e-03	4.273e-01	0.000e+00	1.043e-02	6.687e-03	1.368e-04
74	1.7910e-01	1.894e+00	2.091e-02	1.915e+00	5.943e-02	6.535e-03	4.517e-01	0.000e+00	1.104e-02	7.608e-03	1.579e-04
73	1.9531e-01	1.819e+00	2.129e-02	1.840e+00	6.807e-02	6.926e-03	4.766e-01	0.000e+00	1.170e-02	8.640e-03	1.823e-04
72	2.1293e-01	1.751e+00	2.172e-02	1.772e+00	7.787e-02	7.339e-03	5.018e-01	0.000e+00	1.240e-02	9.792e-03	2.105e-04
71	2.3227e-01	1.688e+00	2.221e-02	1.710e+00	8.894e-02	7.777e-03	5.274e-01	0.000e+00	1.315e-02	1.108e-02	2.433e-04
70	2.5329e-01	1.631e+00	2.275e-02	1.654e+00	1.014e-01	8.242e-03	5.530e-01	0.000e+00	1.394e-02	1.250e-02	2.810e-04
69	2.7621e-01	1.580e+00	2.337e-02	1.603e+00	1.155e-01	8.733e-03	5.787e-01	0.000e+00	1.480e-02	1.408e-02	3.248e-04
68	3.0121e-01	1.533e+00	2.408e-02	1.557e+00	1.314e-01	9.255e-03	6.042e-01	0.000e+00	1.571e-02	1.583e-02	3.756e-04
67	3.2848e-01	1.491e+00	2.489e-02	1.516e+00	1.491e-01	9.811e-03	6.295e-01	0.000e+00	1.669e-02	1.775e-02	4.346e-04
66	3.5820e-01	1.453e+00	2.578e-02	1.479e+00	1.690e-01	1.040e-02	6.544e-01	0.000e+00	1.774e-02	1.986e-02	5.032e-04
65	3.9063e-01	1.420e+00	2.679e-02	1.447e+00	1.911e-01	1.103e-02	6.788e-01	0.000e+00	1.887e-02	2.217e-02	5.828e-04
64	4.2598e-01	1.390e+00	2.789e-02	1.418e+00	2.158e-01	1.170e-02	7.026e-01	0.000e+00	2.007e-02	2.469e-02	6.753e-04
63	4.6453e-01	1.364e+00	2.914e-02	1.393e+00	2.433e-01	1.241e-02	7.256e-01	1.556e-04	2.137e-02	2.744e-02	7.825e-04
62	5.0658e-01	1.341e+00	3.054e-02	1.371e+00	2.737e-01	1.318e-02	7.478e-01	6.162e-04	2.278e-02	3.043e-02	9.080e-04
61	5.5243e-01	1.321e+00	3.213e-02	1.353e+00	3.074e-01	1.399e-02	7.691e-01	1.214e-03	2.431e-02	3.367e-02	1.055e-03
60	6.0243e-01	1.303e+00	3.390e-02	1.337e+00	3.446e-01	1.487e-02	7.894e-01	2.006e-03	2.601e-02	3.718e-02	1.228e-03
59	6.5695e-01	1.289e+00	3.588e-02	1.325e+00	3.855e-01	1.581e-02	8.086e-01	2.928e-03	2.784e-02	4.098e-02	1.430e-03
58	7.1641e-01	1.277e+00	3.811e-02	1.315e+00	4.306e-01	1.682e-02	8.267e-01	4.001e-03	2.985e-02	4.506e-02	1.667e-03
57	7.8125e-01	1.267e+00	4.055e-02	1.307e+00	4.801e-01	1.792e-02	8.436e-01	5.226e-03	3.201e-02	4.946e-02	1.945e-03
56	8.5196e-01	1.259e+00	4.324e-02	1.303e+00	5.311e-01	1.910e-02	8.594e-01	6.601e-03	3.434e-02	5.419e-02	2.270e-03
55	9.2907e-01	1.254e+00	4.621e-02	1.300e+00	5.935e-01	2.036e-02	8.741e-01	8.1[illegible]e-03	3.686e-02	5.927e-02	2.651e-03
54	1.0132e+00	1.250e+00	4.950e-02	1.299e+00	6.582e-01	2.173e-02	8.876e-01	[illegible]	3.961e-02	6.471e-02	3.096e-03
53	1.1049e+00	1.248e+00	5.324e-02	1.301e+00	7.288e-01	2.321e-02	9.000e-01	[illegible]	4.267e-02	7.054e-02	3.623e-03
52	1.2049e+00	1.247e+00	5.745e-02	1.304e+00	8.056e-01	2.481e-02	9.114e-01	[illegible]	4.607e-02	7.677e-02	4.248e-03

51	1.3139e+00	1.248e+00	6.226e-02	1.310e+00	8.890e-01	2.655e-02	9.216e-01	1.594e-02	4.990e-02	8.342e-02	4.993e-03
50	1.4328e+00	1.250e+00	6.751e-02	1.317e+00	9.795e-01	2.844e-02	9.309e-01	1.832e-02	5.401e-02	9.052e-02	5.873e-03
49	1.5625e+00	1.253e+00	7.316e-02	1.326e+00	1.078e+00	3.050e-02	9.393e-01	2.090e-02	5.854e-02	9.810e-02	6.909e-03
48	1.7039e+00	1.257e+00	7.987e-02	1.337e+00	1.184e+00	3.274e-02	9.468e-01	2.367e-02	6.352e-02	1.062e-01	8.133e-03
47	1.8581e+00	1.263e+00	8.710e-02	1.350e+00	1.299e+00	3.518e-02	9.535e-01	2.663e-02	6.899e-02	1.148e-01	9.580e-03
46	2.0263e+00	1.269e+00	9.521e-02	1.364e+00	1.423e+00	3.784e-02	9.594e-01	2.980e-02	7.505e-02	1.240e-01	1.130e-02
45	2.2097e+00	1.275e+00	1.043e-01	1.380e+00	1.556e+00	4.073e-02	9.647e-01	3.317e-02	8.176e-02	1.337e-01	1.333e-02
44	2.4097e+00	1.283e+00	1.144e-01	1.397e+00	1.700e+00	4.388e-02	9.694e-01	3.675e-02	8.919e-02	1.441e-01	1.575e-02
43	2.6278e+00	1.291e+00	1.258e-01	1.416e+00	1.855e+00	4.733e-02	9.735e-01	4.055e-02	9.747e-02	1.550e-01	1.862e-02
42	2.8656e+00	1.299e+00	1.384e-01	1.437e+00	2.022e+00	5.108e-02	9.771e-01	4.456e-02	1.066e-01	1.667e-01	2.201e-02
41	3.1250e+00	1.308e+00	1.525e-01	1.460e+00	2.201e+00	5.517e-02	9.803e-01	4.879e-02	1.166e-01	1.790e-01	2.603e-02
40	3.4078e+00	1.317e+00	1.683e-01	1.485e+00	2.393e+00	5.963e-02	9.830e-01	5.325e-02	1.278e-01	1.921e-01	3.080e-02
39	3.7163e+00	1.326e+00	1.859e-01	1.512e+00	2.599e+00	6.449e-02	9.854e-01	5.792e-02	1.401e-01	2.058e-01	3.644e-02
38	4.0526e+00	1.336e+00	2.053e-01	1.541e+00	2.819e+00	6.977e-02	9.875e-01	6.282e-02	1.537e-01	2.203e-01	4.308e-02
37	4.4194e+00	1.346e+00	2.268e-01	1.572e+00	3.055e+00	7.549e-02	9.893e-01	6.794e-02	1.686e-01	2.356e-01	5.089e-02
36	4.8194e+00	1.355e+00	2.507e-01	1.606e+00	3.307e+00	8.169e-02	9.908e-01	7.328e-02	1.849e-01	2.517e-01	6.007e-02
35	5.2556e+00	1.365e+00	2.771e-01	1.642e+00	3.575e+00	8.839e-02	9.921e-01	7.884e-02	2.029e-01	2.686e-01	7.084e-02
34	5.7313e+00	1.375e+00	3.063e-01	1.682e+00	3.861e+00	9.561e-02	9.933e-01	8.462e-02	2.227e-01	2.862e-01	8.345e-02
33	6.2500e+00	1.385e+00	3.386e-01	1.724e+00	4.166e+00	1.034e-01	9.943e-01	9.062e-02	2.444e-01	3.046e-01	9.819e-02
32	6.8157e+00	1.395e+00	3.742e-01	1.770e+00	4.490e+00	1.117e-01	9.951e-01	9.683e-02	2.682e-01	3.238e-01	1.154e-01
31	7.4325e+00	1.405e+00	4.137e-01	1.819e+00	4.834e+00	1.207e-01	9.959e-01	1.033e-01	2.944e-01	3.438e-01	1.354e-01
30	8.1052e+00	1.415e+00	4.572e-01	1.873e+00	5.198e+00	1.302e-01	9.965e-01	1.099e-01	3.230e-01	3.645e-01	1.587e-01
29	8.8388e+00	1.425e+00	5.052e-01	1.930e+00	5.584e+00	1.404e-01	9.970e-01	1.167e-01	3.545e-01	3.858e-01	1.856e-01
28	9.6388e+00	1.435e+00	5.582e-01	1.997e+00	5.992e+00	1.513e-01	9.975e-01	1.238e-01	3.890e-01	4.078e-01	2.168e-01
27	1.0511e+01	1.445e+00	6.167e-01	2.061e+00	6.422e+00	1.627e-01	9.979e-01	1.311e-01	4.268e-01	4.304e-01	2.527e-01
26	1.1463e+01	1.454e+00	6.811e-01	2.135e+00	6.875e+00	1.749e-01	9.982e-01	1.385e-01	4.683e-01	4.534e-01	2.941e-01
25	1.2500e+01	1.464e+00	7.521e-01	2.216e+00	7.352e+00	1.877e-01	9.985e-01	1.461e-01	5.138e-01	4.769e-01	3.416e-01
24	1.3631e+01	1.473e+00	8.304e-01	2.304e+00	7.853e+00	2.012e-01	9.987e-01	1.540e-01	5.637e-01	5.007e-01	3.960e-01
23	1.4865e+01	[illegible]	9.165e-01	2.399e+00	8.378e+00	2.153e-01	9.989e-01	1.620e-01	6.183e-01	5.248e-01	4.582e-01
22	1.6210e+01	1.492e+00	1.011e+00	2.503e+00	8.927e+00	2.301e-01	9.991e-01	1.702e-01	6.780e-01	5.490e-01	5.290e-01
21	1.7678e+01	1.501e+00	1.115e+00	2.616e+00	9.500e+00	2.455e-01	9.992e-01	1.786e-01	7.434e-01	5.733e-01	6.094e-01
20	1.9278e+01	1.509e+00	1.230e+00	2.739e+00	1.010e+01	2.614e-01	9.993e-01	1.871e-01	8.149e-01	5.976e-01	7.006e-01
19	2.1022e+01	1.518e+00	1.356e+00	2.874e+00	1.072e+01	2.779e-01	9.994e-01	1.958e-01	8.932e-01	6.218e-01	8.036e-01
18	2.2925e+01	1.527e+00	1.494e+00	3.021e+00	1.137e+01	2.950e-01	9.995e-01	2.047e-01	9.788e-01	6.457e-01	9.197e-01
17	2.5000e+01	1.535e+00	1.646e+00	3.182e+00	1.203e+01	3.125e-01	9.996e-01	2.137e-01	1.072e+00	6.692e-01	1.050e+00
16	2.7263e+01	1.543e+00	1.813e+00	3.357e+00	1.273e+01	3.305e-01	9.997e-01	2.229e-01	1.175e+00	6.923e-01	1.197e+00
15	2.9730e+01	1.552e+00	1.996e+00	3.548e+00	1.344e+01	3.488e-01	9.997e-01	2.322e-01	1.286e+00	7.149e-01	1.361e+00
14	3.2421e+01	1.560e+00	2.197e+00	3.757e+00	1.418e+01	3.675e-01	9.998e-01	2.417e-01	1.409e+00	7.369e-01	1.544e+00
13	3.5355e+01	1.568e+00	2.417e+00	3.985e+00	1.494e+01	3.865e-01	9.998e-01	2.514e-01	1.542e+00	7.583e-01	1.749e+00
12	3.8555e+01	1.575e+00	2.659e+00	4.234e+00	1.572e+01	4.057e-01	9.998e-01	2.611e-01	1.688e+00	7.789e-01	1.976e+00
11	4.2045e+01	1.583e+00	2.923e+00	4.506e+00	1.651e+01	4.250e-01	9.999e-01	2.710e-01	1.846e+00	7.987e-01	2.228e+00
10	4.5850e+01	1.591e+00	3.213e+00	4.804e+00	1.733e+01	4.444e-01	9.999e-01	2.810e-01	2.020e+00	8.178e-01	2.508e+00
9	5.0000e+01	1.598e+00	3.531e+00	5.129e+00	1.817e+01	4.639e-01	9.999e-01	2.912e-01	2.209e+00	8.359e-01	2.817e+00
8	5.4525e+01	1.606e+00	3.879e+00	5.484e+00	1.902e+01	4.833e-01	9.999e-01	3.014e-01	2.416e+00	8.531e-01	3.159e+00
7	5.9460e+01	1.613e+00	4.260e+00	5.873e+00	1.989e+01	5.026e-01	9.999e-01	3.118e-01	2.641e+00	8.694e-01	3.536e+00
6	6.4842e+01	1.620e+00	4.677e+00	6.297e+00	2.078e+01	5.219e-01	9.999e-01	3.223e-01	2.887e+00	8.848e-01	3.951e+00
5	7.0711e+01	1.627e+00	5.133e+00	6.760e+00	2.167e+01	5.409e-01	9.999e-01	3.328e-01	3.155e+00	8.993e-01	4.409e+00
4	7.7111e+01	1.634e+00	5.632e+00	7.266e+00	2.259e+01	5.597e-01	1.000e+00	3.435e-01	3.447e+00	9.129e-01	4.911e+00
3	8.4090e+01	1.641e+00	6.178e+00	7.819e+00	2.351e+01	5.782e-01	1.000e+00	3.543e-01	3.765e+00	9.257e-01	5.463e+00
2	9.1700e+01	1.648e+00	6.774e+00	8.422e+00	2.445e+01	5.964e-01	1.000e+00	3.652e-01	4.111e+00	9.377e-01	6.069e+00
1	1.0000e+02	1.654e+00	7.426e+00	9.080e+00	2.540e+01	6.142e-01	1.000e+00	3.761e-01	4.489e+00	9.489e-01	6.733e+00

OEND OF DATPAC SUBROUTINE
OEND OF PROGRAM XGEN

095200

INP

USER NUMBER	095200
WORKER MACHINE	Y
DATE SENT	10-Oct 1985
TIME SENT	15:17:31
XEROX UNIT	A
PAGES DATE	10 Oct 1985
PAGES TIME	15 18 29 JOB [illegible] pages1

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1 ***************************************
  *                                     *
  *    PROGRAM ITS    DECEMBER 16, 1984 *
  *            VERSION 1.0              *
  *                                     *
  ***************************************
  *             A C C E P T             *
  *                                     *
  ***************************************
0NUMBER OF MATERIALS
     2
0*******************************************************
 * GAMMA RAY CROSS SECTION DATA FOR MATERIAL NUMBER   1 *
 *******************************************************
0MPAIR  NTAB  MTAX
   25     6    39     7     3     2     3     4
0ENERGIES (MEV)
 1000.000000  800.000000  600.000000  500.000000  400.000000  300.000000
  200.000000  150.000000  100.000000   80.000000   60.000000   50.000000
   40.000000   30.000000   20.000000   15.000000   10.000000    8.000000
    6.000000    5.000000    4.000000    3.000000    2.000000    1.500000
    1.000000    0.800000    0.600000    0.500000    0.400000    0.300000
    0.200000    0.150000    0.100000    0.080000    0.060000    0.050000
    0.040000    0.030000    0.027940
    0.027940    0.020000    0.015000    0.010000    0.008000    0.006000
    0.004238
    0.004238    0.004000    0.003938
    0.003938    0.003730
    0.003730    0.003000    0.002144
    0.002144    0.002000    0.001500    0.001000
0TOTAL ATTENUATION COEFFICIENTS (CM2/G)
    0.072765    0.072086    0.071064    0.070108    0.069253    0.067681
    0.064989    0.062724    0.059391    0.056597    0.053592    0.051730
    0.049243    0.045587    0.040515    0.038040    0.035902    0.035012
    0.034265    0.034193    0.034702    0.036525    0.041606    0.047119
    0.058324    0.066125    0.078504    0.088619    0.105375    0.140815
    0.256863    0.459567    1.231901    2.221800    4.849174    7.973909
   14.587593   31.164482   37.392754
    6.399423   16.079271   35.506170  108.562369  199.314251  430.412449
 1051.376794
  926.192751 1076.239060 1120.238487
  848.410361  973.346916
  400.500743  709.298018 1633.529058
 1127.930930 1332.818662 2623.326525 6389.511380
0RATIO OF SCATTERING PLUS PAIR PRODUCTION TO TOTAL ATTENUATION COEFFICIENTS
    0.999991    0.999988    0.999984    0.999980    0.999975    0.999966
    0.999947    0.999926    0.999882    0.999845    0.999781    0.999726
    0.999637    0.999471    0.999084    0.998666    0.997771    0.997034
    0.995702    0.994574    0.992817    0.989768    0.983155    0.975570
    0.956872    0.938869    0.900503    0.862535    0.794654    0.663924
    0.418614    0.255285    0.105735    0.061530    0.029729    0.018604
    0.010481    0.005065    0.004250
    0.024833    0.010154    0.004670    0.001559    0.000855    0.000399
    0.000165
    0.000187    0.000161    0.000155
    0.000204    0.000178
    0.000433    0.000245    0.000107
    0.000155    0.000131    0.000067    0.000027
0RATIO OF SCATTERING TO SCATTERING PLUS PAIR PRODUCTION ATTENUATION COEFFICIENTS
    0.002922    0.003679    0.004958    0.005997    0.007578    0.010266
    0.015819    0.021566    0.033314    0.042926    0.058763    0.071528
    0.091183    0.125583    0.196442    0.261915    0.376217    0.453464
    0.567301    0.643989    0.736247    0.841514    0.945837    0.986533
    1.000000
```

```
OK SHELL IONIZATION DATA
OBINDING ENERGY (MEV), PHOTOEFFECT EFFICIENCY AND FLUORESCENT EFFICIENCY
    0 027940     0 832399     0 827839
OK X-RAY ENERGIES (MEV)
    0 024710     0 024710     0 024710     0 024710
OK X RAY ACCUMULATED RELATIVE INTENSITIES
    1 000000     1 000000     1 000000     1 000000
OAUGER ELECTRON ENERGIES (MEV)
    0 024710     0.024710     0 024710
OAUGER ELECTRON ACCUMULATED RELATIVE INTENSITIES
    1 000000     1 000000     1 000000
O*********************************************************
 * GAMMA RAY CROSS SECTION DATA FOR MATERIAL NUMBER   2  *
 *********************************************************
OMPAIR  NTAB  MTAX
   25     9    41     2     8     3     2     2     2     2     2
OENERGIES (MEV)
 1000 000000  800 000000  600 000000  500 000000  400 000000  300.000000
  200 000000  150 000000  100 000000   80 000000   60 000000   50 000000
   40 000000   30 000000   20 000000   15 000000   10.000000    8.000000
    6.000000    5 000000    4 000000    3 000000    2 000000    1.500000
    1.000000    0 800000    0 600000    0 500000    0 400000    0 300000
    0 200000    0.150000    0 100000    0 080000    0 060000    0 050000
    0 040000    0 030000    0 020000    0 015000    0 011867
    0 011867    0 010367
    0.010367    0 010000    0.008000    0 006000    0 004000    0.003000
    0.002000    0 001530
    0 001530    0 001500    0 001359
    0 001359    0 001323
    0.001323    0.001300
    0 001300    0 001142
    0.001142    0.001115
    0 001115    0.001000
OTOTAL ATTENUATION COEFFICIENTS (CM2/G)
    0 060173    0 059621    0 058788    0 058165    0 057303    0.056005
    0 053787    0 051934    0 049963    0 046697    0 044178    0 042643
    0 040706    0 038095    0 034773    0 033158    0 031708    0 031226
    0 031146    0 031548    0.032637    0 035130    0 040841    0.046461
    0 056969    0 063728    0 073495    0 080568    0 090771    0.108617
    0 156168    0 232022    0 519524    0 897401    1 931400    3.204058
    6 011995   13 582092   42 219955   92 061788  169 049007
   88 555587  125 134417
   32 240310   35 706283   66 753770  147 467145  443.091478  955.117843
 2732 050663 5257 113182
 4921.179093 5143 463319 6436 545700
 5490 863273 5988 838578
 3846 426669 3993 258492
 3525 331716 4840 813860
 3578 786478 3983 385737
 1390.333237 1775 183143
ORATIO OF SCATTERING PLUS PAIR PRODUCTION TO TOTAL ATTENUATION COEFFICIENTS
    0 999996    0 999995    0 999994    0 999992    0 999990    0 999987
    0 999980    0 999972    0 999955    0 999941    0 999916    0 999895
    0 999862    0 999801    0 999667    0 999525    0 999223    0 998982
    0 998566    0 998229    0 997722    0 996868    0 995042    0 992921
    0 987487    0 982006    0 969600    0 956339    0 929900    0 867642
    0 694056    0 509703    0 252731    0 153559    0 075239    0 046670
    0 025634    0 011714    0 003898    0 001820    0 001002
    0 001913    0 001361
    0 005284    0 004778    0 002575    0 001174    0 000394    0 000183
    0 000064    0 000034
    0 000016    0 000034    0 000027
    0 000032    0 000029
    0 000046    0 000044
```

```
     0 000050     0 000036
     0 000049     0 000044
     0 000127     0 000099
ORATIO OF SCATTERING TO SCATTERING PLUS PAIR PRODUCTION ATTENUATION COEFFICIENTS
     0 003562     0 004484     0 006042     0 007307     0 009231     0 012506
     0 019266     0 026255     0 040730     0 052435     0 071847     0 087451
     0 111168     0 151439     0 230586     0 302629     0 428773     0 511521
     0 627310     0 701006     0 785222     0 875673     0 959669     0 990910
     1 000000
OK SHELL IONIZATION DATA
OBINDING ENERGY (MEV), PHOTOEFFECT EFFICIENCY AND FLUORESCENT EFFICIENCY
     0 011867     0 476827     0 520756
OK X-RAY ENERGIES (MEV)
     0 010690     0 010690     0 010690     0 010690
OK X-RAY ACCUMULATED RELATIVE INTENSITIES
     1 000000     1 000000     1 000000     1 000000
OAUGER ELECTRON ENERGIES (MEV)
     0 010690     0 010690     0 010690
OAUGER ELECTRON ACCUMULATED RELATIVE INTENSITIES
     1 000000     1 000000     1 000000
1*******************************************************
 *    ELECTRON CROSS SECTION DATA FROM PROGRAM DATPAC    *
 *******************************************************
ONUMBER OF SETS ON DATAPAC TAPE -    2
0*******************100 0 MEV CROSS SECTIONS FOR PHOTOCONDUCTORS                                  *******************

OMATERIAL        DENSITY          DETOUR
        1  0 47800e+01  0 73100e+00
            Z                A                W
  0 15000e+02  0 30974e+02  0 21200e+00
  0 49000e+02  0 11482e+03  0 78800e+00
  NSET  ITRM  IZIP  ISGN  ISUB  INAL  ICYC  NCYC  NMAX        EMAX              EMIN              RMAX         LMAT
     1     5     0     1    40     1     1     8    64  1 0000000e+02  3 9062500e 01  2 3175160e+01     2
  DATAPREP DATA FOR DATAPAC SET    1    64    33    40   121  2 317516e+01


OMATERIAL        DENSITY          DETOUR
        2  0 53200e+01  0 39500e+00
            Z                A                W
  0 31000e+02  0 69720e+02  0 48200e+00
  0 33000e+02  0 74922e+02  0 51800e+00
  NSET  ITRM  IZIP  ISGN  ISUB  INAL  ICYC  NCYC  NMAX        EMAX              EMIN              RMAX         LMAT
     2     5     0     1    40     1     1     8    64  1 0000000e+02  3 9062500e 01  2 5400030e+01     2
  DATAPREP DATA FOR DATAPAC SET    2    64    31    40   121  2 540003e+01

O COLLISION / TOTAL DE/DX RATIOS FOR DATAPAC SET    2
O CUMULATIVE BREMSSTRAHLUNG CROSS SECTIONS FOR DATAPAC SET    2
O CUMULATIVE BREMSSTRAHLUNG ANGULAR DISTRIBUTIONS FOR DATAPAC SET    2
O LANGAUSS - EQUIPROBABLE ENDPOINTS FOR INTERPOLATION
O K X-RAY PRODUCTION FOR DATAPAC SET    2
O PHOTOELECTRON ANGULAR DISTRIBUTIONS
O PAIR ELECTRON ENERGY DIVISION DISTRIBUTION (LEAD)
1**************************
 *   BEGIN READING INPUT   *
 **************************
 TITLE
  100 0 MEV KEIPPER TEST PROGRAM
 **************GEOMETRY*******************************
 GEOMETRY 1 0


                                                    BODY DATA

 RPP 0 00 0 50 0 00 0 10 0 00 0 05
 REAL DATA FOR BODY    1 IS STORED IN FPD ARRAY LOCATIONS     3 THROUGH     8
```

```
SPH 0.00 0.00 0.00 2.0
REAL DATA FOR BODY    2 IS STORED IN FPD ARRAY LOCATIONS    11 THROUGH    14
SPH 0.00 0.00 0.00 4.0
REAL DATA FOR BODY    3 IS STORED IN FPD ARRAY LOCATIONS    17 THROUGH    20
END
NUMBER OF BODIES        3

                                         INPUT ZONE DATA
21 +1
22 +2 -1
23 +3 -2
END
0  COMPARISON OF GEOMETRY REQUIREMENTS VS ALLOCATIONS
 LENGTH OF ARRAY CONTAINING REAL BODY DATA               / IFPD    =    20  /    1000
 NUMBER OF INPUT ZONES                                   / INZON   =     3  /     100
 NUMBER OF CODE ZONES                                    / INUMR   =     3  /     100
 LENGTH OF GEOMETRY ARRAY CONTAINING INTEGER DATA        / IIMA    =    65  /    1000
 LENGTH OF ARRAY CONTAINING CODE ZONE BODY DATA          / IJTY    =     2  /      50

 CODE ZONE     INPUT ZONE     ZONE DATA LOC      NO  OF BODIES
     1              1               16                 1
     2              2               20                 2
     3              3               28                 2

 OPTION 1 WAS USED IN CALCULATING VOLUMES FOR    3 INPUT ZONES
   IVOPT         MEANING
     0      - ALL VOLUMES SET TO 1.0
     1      - READ INPUT VOLUMES
     2        USER LOGIC TO COMPUTE VOLUMES

           VOLUMES(CM**3)
   ZONE          1              2              3
 VOLUME   2.500e 03    3.350e+01     2.679e+02
 *MAT ECUT PTCZ
 1
 0
 0
 ********************SOURCE************************
 ELECTRONS
 ENERGY 100.0
 POSITION 0.0 0.0 0.0
 RADIUS 0.5
 DIRECTION 0.0
 CUTOFFS 0.05 0.001
 *******************OUTPUT OPTIONS*******************
 ELECTRON-ESCAPE
 NBINE 10
 PHOTON-ESCAPE
 NBINE 10
 ELECTRON-FLUX 1 1
 NBINE 10
 PHOTON-FLUX 1 1
 NBINE 10
 *********************OTHER OPTIONS*******************
 HISTORIES 1000000
0 EOF ON UNIT  5 BEGIN PROCESSING   INPUT
1*****************************************************
 *   COMPARISON OF STORAGE REQUIREMENTS VS ALLOCATIONS   *
 *****************************************************
0NUMBER OF MATERIALS ON CROSS SECTION FILE                       / INMT          2  /      5
```

```
LENGTH OF ELECTRON CROSS SECTION ENERGY GRID                                    / INMAX  =   64 /   64
ELECTRON ENERGY GRID LENGTH FOR SAMPLING BREMS. PHOTON ENERGY                   / IMTOP      65 /   65
PHOTON ENERGY GRID LENGTH FOR SAMPLING BREMS  PHOTON ENERGY                     / IKTOP  =   49 /   49
ELECTRON ANGLE GRID LENGTH FOR SAMPLING ELECTRON SCATTERING ANGLE               / INMAX  =   33 /   33
PHOTON ANGLE GRID LENGTH FOR SAMPLING BREMS  PHOTON ANGLE                       / INPANG =   21 /   21
PHOTON ENERGY GRID LENGTH FOR SAMPLING BREMS  PHOTON ANGLE                      / INRANG =   25 /   25
ELECTRON ENERGY GRID LENGTH FOR SAMPLING BREMS  PHOTON ANGLE                    / INEANG =    9 /    9
PHOTON ENERGY GRID LENGTH FOR SAMPLING PHOTO ELECTRON DIRECTION                 / INEEL  =   13 /   17
ELECTRON ANGLE GRID LENGTH FOR SAMPLING PHOTO ELECTRON DIRECTION                / INPEL  =   21 /   21
PHOTON ENERGY GRID LENGTH FOR SAMPLING PAIR ELECTRON ENERGY                     / INEPS  =    9 /   17
ELECTRON ENERGY GRID LENGTH FOR SAMPLING PAIR ELECTON ENERGY                    / INPPS  =   21 /   21
GAUSSIAN FUNCTION GRID FOR SAMPLING ELECTRON ENERGY LOSS STRAGGLING             / INGAS  =  100 /  100
LANDAU FUNCTION GRID FOR SAMPLING ELECTRON ENERGY LOSS STRAGGLING               / INLAN  =  500 /  500
MAXIMUM NUMBER OF TABLES OF PHOTON CROSS SECTIONS                               / INTAB  =    9 /   15
MAXIMUM LENGTH OF PHOTON CROSS SECTION TABLE                                    / IMTAX  =   41 /   48
NUMBER OF ELECTRON ESCAPE ENERGY BINS                                           / IJMAX  =   10 /   50
NUMBER OF PHOTON ESCAPE ENERGY BINS                                             / IJPMAX =   10 /   50
NUMBER OF ELECTRON ESCAPE POLAR ANGLE BINS                                      / IKMAX  =   18 /   36
NUMBER OF PHOTON ESCAPE POLAR ANGLE BINS                                        / IKPMAX =   18 /   36
LENGTH OF SOURCE SPECTRUM ENERGY GRID                                           / IJSPEC =    0 /   51
NUMBER OF PULSE HEIGHT ENERGY BINS                                              / IJSMAX =    0 /   53
NUMBER OF ELECTRON FLUX ENERGY BINS                                             / IJEMAX =   10 /   50
NUMBER OF PHOTON FLUX ENERGY BINS                                               / IJEMXP =   10 /   50
NUMBER OF ELECTRON FLUX ZONES                                                   / INLF   =    1 /   10
NUMBER OF PHOTON FLUX ZONES                                                     / INLFP  =    1 /   10
NUMBER OF PROBLEM ZONES                                                         / INZON  =    3 /  100
SIZE OF DOUBLY DIFFERENTIAL BREMS DISTRIBUTION                                  / NCHANG = 4725 / 4725
SIZE OF SINGLY DIFFERENTIAL BREMS DISTRIBUTION                                  / NBDTS  = 3185 / 3185
SIZE OF GOUDSMIT SAUNDERSON ANGULAR DISTRIBUTION                                / NGG    = 2112 / 2112
NO. OF ELECTRON ESCAPE AZIMUTHAL ANGLE BINS                                     / IKMAZ  =    1 /    1
NO. OF PHOTON ESCAPE AZIMUTHAL ANGLE BINS                                       / IKPMAZ =    1 /    1
0************* GLOBAL ELECTRON CUTOFF ENERGY BELOW ELECTRON ENERGY LIST   CUTOFF ENERGY HAS BEEN CHANGED TO  0.408302e+00
1********************************
 *   GEOMETRY DEPENDENT INPUT   *
 ********************************
0                       ELECTRON    PHOTON
  INPUT                  CUTOFF   STRETCHING
  ZONE  MATERIAL         (MEV)      FACTOR
    1       1         4 083e-01   1.000e+00
    2       0         4 083e-01   1.000e+00
    3       0         4 083e-01   1.000e+00
1************************
 *  SOURCE INFORMATION  *
 ************************
0SOURCE ELECTRONS
0THE MAXIMUM SOURCE ENERGY IS     100 00000 MEV
0THE GLOBAL ELECTRON CUTOFF ENERGY IS       0 40830 MEV
0THE PHOTON CUTOFF ENERGY IS       0 00100 MEV
0COORDINATES OF THE POINT SOURCE OR OF THE CENTER OF THE BEAM (DISK) SOURCE ARE
     X =  0 00000e+00 CM             Y =  0 00000e+00 CM             Z =  0.00000e+00 CM
0THE RADIUS OF THE BEAM (DISK) SOURCE IS =   5 0000e 01 CM
0REFERENCE DIRECTION FOR ANGULAR DISTRIBUTION IS DEFINED BY
     THETA =   0 0000 DEGREES             PHI =   0 0000 DEGREES
0MONODIRECTIONAL SOURCE IN REFERENCE DIRECTION
0THE STANDARD ERROR ESTIMATES ARE BASED ON     10 BATCHES OF   100000 HISTORIES EACH
1********************
 *  OUTPUT OPTIONS  *
 ********************
0ELECTRON ESCAPE ENERGY CLASSIFICATIONS (MEV)
    90 00000     80 00000     70 00000     60 00000     50 00000     40 00000
    30 00000     20 00000     10 00000      0 40830
0ELECTRON ESCAPE POLAR ANGLE CLASSIFICATIONS (DEGREES)
    10 00000     20 00000     30 00000     40 00000     50 00000     60 00000
    70 00000     80 00000     90 00000    100 00000    110 00000    120 00000
```

```
   130 00000    140 00000    150 00000    160 00000    170 00000    180 00000
OELECTRON ESCAPE AZIMUTH ANGLE CLASSIFICATIONS (DEGREES)
   180 00000
OPHOTON ESCAPE ENERGY CLASSIFICATIONS (MEV)
    90 00000     80 00000     70 00000     60 00000     50 00000     40 00000
    30 00000     20 00000     10 00000      0 00100
OPHOTON-ESCAPE POLAR ANGLE CLASSIFICATIONS (DEGREES)
    10 00000     20 00000     30 00000     40 00000     50 00000     60 00000
    70 00000     80 00000     90 00000    100 00000    110 00000    120 00000
   130 00000    140 00000    150 00000    160 00000    170 00000    180 00000
OPHOTON ESCAPE AZIMUTH ANGLE CLASSIFICATIONS (DEGREES)
   180 00000
OELECTRON-FLUX ENERGY CLASSIFICATIONS (MEV)
    90 00000     80 00000     70 00000     60 00000     50 00000     40 00000
    30 00000     20 00000     10 00000      0 40830
OPHOTON-FLUX ENERGY CLASSIFICATIONS (MEV)
    90 00000     80 00000     70 00000     60 00000     50 00000     40 00000
    30 00000     20 00000     10 00000      0 00100
1**********************
 *  PHYSICAL OPTIONS  *
 **********************
OELECTRON COLLISION AND RADIATION ENERGY LOSS STRAGGLING
OKNOCK ON ELECTRON PRODUCTION
ONO COUPLED INELASTIC SCATTERING DEFLECTIONS
OBREMSSTRAHLUNG AND CHARACTERISTIC X RAY QUANTA FOLLOWED
OBREMSSTRAHLUNG INTRINSIC ANGLE OF EMISSION FROM TABULATED DISTRIBUTION
OPHOTON PRODUCED ELECTRONS FOLLOWED
O        MATERIAL NO   1
 ELECTRON RANGE AT MAXIMUM SOURCE ENERGY IS       0 23175e+02 (G/CM**2)
 K X RAY QUANTA FOLLOWED
 ELECTRON IMPACT IONIZATION SAMPLED
O        MATERIAL NO   2
 ELECTRON RANGE AT MAXIMUM SOURCE ENERGY IS       0 25400e+02 (G/CM**2)
 K X RAY QUANTA FOLLOWED
 ELECTRON IMPACT IONIZATION SAMPLED
OANNIHILATION QUANTA FOLLOWED
1*************************************************************************
 *                                                                       *
 *     100 0 MEV KEIPPER TEST PROGRAM                                    *
 *                                                                       *
 *************************************************************************
OTHE PROBLEM IS  100  PERCENT COMPLETE   TIME TO FINISH IS        0.000 SECONDS  AVERAGE TIME PER BATCH IS       16 436
OAVERAGE SOURCE ENERGY = 1 0000e+02  0 MEV
OTHE INITIAL RANDOM NUMBER OF THIS RUN IS 0000000000000000000
 THE INITIAL RANDOM NUMBER OF THE CURRENT BATCH IS 0000740113023554 3605
 THE  FINAL  RANDOM NUMBER OF THE CURRENT BATCH IS 0000711276262605 5015
O  ------------------------------ HISTORIES ----------------------------------  RLJ    REJ     -- STEPS
     PRIM      SEC     KNOCK      P E     PAIR     COM    AUGER     BREM      RAD     XRAY    LAND    PEAL      PRIM
   1000000     2567     2495        1      56       13       0     12802    12826     4449      10      0     1063367
O                             ENERGY (MEV)      AVE ENERGY (MEV)     NUMBER/PRIMARY     NUMBER GENERATED
 FIRST KNOCK (ABOVE TCUT)      4 8227e 03        1 9454e+00          2 4790e 03             2479
 TOTAL KNOCK (ABOVE TCUT)      4 8333e 03        1 9374e+00          2 4950e 03             2495
 PHOTO ELECTRON                9 0896e 05        2 6797e 02          3 3920e 03             3392
 PAIR                          6 4565e 04        1 1132e+01          5 8000e 05               58
 COMPTON                       2 1583e 05        1 8768e 01          1 1500e 04              115
 AUGER                         2 1720e 05        2 4710e 02          8 7900e 04              879
 FIRST BREMSSTRAHLUNG          1 2843e 01        1 0275e+01          1 2500e 02            12500
 TOTAL BREMSSTRAHLUNG          1 2848e 01        1 0017e+01          1 2826e 02            12826
 K X RAY(P IONIZATION)         2 0756e 06        2 4710e 02          8 4000e 05               84
 K X RAY(E IONIZATION)         1 0786e 04        2 4710e 02          4 3650e 03             4365
 ANNIHILATION QUANTA           3 0659e 06        5 1098e 01          6 0000e 06                6

1UNSCATTERED PRIMARY PHOTONS    NUMBER AND ENERGY FRACTIONS
 0 00e+00 99 0 00e+00 99
```

```
***UNSCATTERED PRIMARY PHOTONS ARE EXCLUDED FROM ALL SUBSEQUENT PHOTON ESCAPE TALLIES***
0NUMBER ESCAPE FRACTIONS     KNOCK ON AND PHOTON GENERATED ELECTRONS, ANNIHILATION RADIATION, K X RAYS (MATERIAL NO )
0                                                        TOTAL ESCAPE
        KNOCK            P SEC           ANNIH      K X RAY(1)    K X RAY(2)    K X RAY(3)    K X RAY(4)    K X RAY(5)
   1 46e 03  3    6 10e 05 19    6 00e 06 71    1 34e 03  2    0 00e+00 99

0                                              NUMBER AND ENERGY ESCAPE FRACTIONS
0                                                        TOTAL ESCAPE
0                                  ELECTRON                          ----------- PHOTON  ----
                        NUMBER      ENERGY       COUNTS       NUMBER       ENERGY       COUNTS

                   1 00e+00  0 9 99e-01  0     1001518  1.38e-02  1 1.28e-03  2       13836
1                                                ENERGY AND CHARGE DEPOSITION
                                            (NORMALIZED TO ONE INCIDENT PARTICLE)
                                      ENERGY(MEV)                                                CHARGE(ELECTRONS)
 ZONE MAT          PRIM           KNOCK          G SEC          TOTAL              PRIM         KNOCK          G SEC          TOTAL

    1     1    2 174e 02  1   4 112e 03  6   4 449e 06 81   1 762e 02  1      0 000e+00 99   1 945e 03  3  -1 140e-04 11 -2 059e 01  1
    2     0    0 000e+00 99   0 000e+00 99   0 000e+00 99   0 000e+00 99      0 000e+00 99   0.000e+00 99   0 000e+00 99   0 000e+00 99
    3     0    0 000e+00 99   0 000e+00 99   0 000e+00 99   0 000e+00 99      0 000e+00 99   0.000e+00 99   0 000e+00 99   0 000e+00 99
0   TOTAL      2.174e 02  1   4 112e 03  6   4 449e 06 81   1 762e-02  1      0 000e+00 99  -1.945e-03  3  -1 140e-04 11 -2.059e 01  1
0 THE ENERGY CONSERVATION FRACTION IS       0 99999862823150+00  0
1FLUX CALCULATION   ELECTRONS LEFT AT FLUX CUTOFF ENERGY (NUMBER, NORMALIZED TO ONE INCIDENT PARTICLE)
        1
 1.03e-03  3
1                                                  ELECTRON FLUX DISTRIBUTION
                                 (TRACK LENGTH/VOLUME MEV, NORMALIZED TO ONE INCIDENT PARTICLE)
OE(MEV)   ZONE=      1

   90 0000     1 23e 01   1
   80 0000     1 24e 03   2
   70 0000     6 27e 04   5
   60 0000     4 20e 04   7
   50.0000     3 19e 04   6
   40 0000     2 23e 04   8
   30 0000     2 05e 04   6
   20 0000     1 52e 04  10
   10 0000     1 75e 04   9
    0 4083     2 94e 03   4
1                                                   PHOTON FLUX DISTRIBUTION
                                 (TRACK LENGTH/VOLUME MEV, NORMALIZED TO ONE INCIDENT PARTICLE)
OE(MEV)   ZONE=      1

   90 0000     6 98e 05  17
   80 0000     1 19e 04   8
   70 0000     1 46e 04   9
   60 0000     2 03e 04   8
   50 0000     2 33e 04   8
   40 0000     3 14e 04   8
   30 0000     3 91e 04   8
   20 0000     5 87e 04   6
   10 0000     1 19e 03   2
    0 0010     1 23e 02   1

1                                             ENERGY SPECTRA OF ESCAPING ELECTRONS
                                        (NUMBER/MEV, NORMALIZED TO ONE INCIDENT PARTICLE)
         E (MEV)
  100 0000      90 0000    9 97e 02   0
   90.0000 -    80 0000    1 19e 04   2
   80 0000      70 0000    5 97e 05   4
   70 0000      60 0000    3 90e 05   7
   60 0000      50 0000    3 08e 05   5
   50 0000      40 0000    2 24e 05   5
   40 0000      30 0000    2 12e 05   5
```

30 0000 -	20 0000	1 67e 05	9
20 0000	10 0000	1 80e 05	7
10 0000	0 4083	1 55e 04	3

ANGULAR DISTRIBUTIONS OF ESCAPING ELECTRONS
(NUMBER/SR, NORMALIZED TO ONE INCIDENT PARTICLE)

0

THETA (DEG)	PHI(DEG)	0 000 180 000	
0 0000	10 0000	1 05e+01	0
10 0000 -	20 0000	6 56e 04	10
20 0000	30 0000	4 77e 04	5
30 0000 -	40 0000	3 80e 04	5
40 0000 -	50 0000	2 36e 04	9
50 0000	60 0000	1 92e 04	8
60 0000 -	70 0000	1 09e 04	8
70 0000 -	80 0000	6 43e 05	8
80 0000	90 0000	5 22e 05	16
90 0000	100 0000	2 93e 05	16
100 0000 -	110 0000	2 27e 05	23
110 0000 -	120 0000	2 82e 05	22
120 0000 -	130 0000	3 23e 05	18
130 0000 -	140 0000	3 23e 05	20
140 0000 -	150 0000	3 98e 05	15
150 0000 -	160 0000	3 24e 05	25
160 0000	170 0000	4 59e 05	30
170.0000 -	180 0000	5 24e 05	61

0

ENERGY SPECTRA AND ANGULAR DISTRIBUTIONS OF ESCAPING ELECTRONS
AZIMUTHAL INTERVAL IS 0 00000 TO 180.00000 DEGREES
(NUMBER/(MEV·SR), NORMALIZED TO ONE PARTICLE)

0

E (MEV)	THETA-	0 000 10 000		10 000 20 000		20 000 30 000		30 000 40 000		40 000 50 000		50 000 60 000		60 000 70 000		70.000 80.000		80 000 90 000	
100 0000 -	90 0000	1 04e+00	0	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99
90 0000 -	80 0000	1 24e 03	2	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0.00e+00	99	0 00e+00	99
80 0000 -	70 0000	6.24e 04	4	0 00e+00	99	2 16e 07	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0.00e+00	99	0 00e+00	99	0 00e+00	99
70 0000 -	60 0000	4 09e 04	7	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99
60.0000 -	50 0000	3 23e 04	5	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0.00e+00	99	0 00e+00	99
50 0000 -	40 0000	2 33e 04	6	7 06e 07	67	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99
40 0000 -	30 0000	2 18e 04	6	1 41e 06	55	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0.00e+00	99	0 00e+00	99	0 00e+00	99
30 0000 -	20 0000	1 64e 04	9	3 53e 06	21	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0.00e+00	99	0 00e+00	99	0 00e+00	99
20 0000 -	10 0000	1 44e 04	8	1 20e 05	22	1 51e 06	30	3 18e 07	67	0 00e+00	99	0 00e+00	99	0 00e+00	99	0.00e+00	99	0 00e+00	99
10.0000	0 4083	1 32e 04	11	5 00e 05	9	4 80e 05	5	3 93e 05	5	2 46e 05	9	2 00e 05	8	1 13e 05	8	6.70e-06	8	5 [illegible]	[illegible]

0

ENERGY SPECTRA AND ANGULAR DISTRIBUTIONS OF ESCAPING ELECTRONS
AZIMUTHAL INTERVAL IS 0 00000 TO 180.00000 DEGREES
(NUMBER/(MEV·SR), NORMALIZED TO ONE PARTICLE)

0

E (MEV)	THETA-	90 000 100 000		100 000 110 000		110 000 120 000		120 000 130 000		130 000 140 000		140 000 150 000		150 000 160 000		160 000 170 000		170 000 180 000	
100 0000	90 0000	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	[illegible]
90 0000	80 0000	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	[illegible]
80 0000	70 0000	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	[illegible]
70 0000	60 0000	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99
60 0000	50 0000	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99
50 0000	40 0000	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	[illegible]
40 0000 -	30 0000	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99
30 0000 -	20 0000	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	[illegible]
20 0000	10 0000	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	[illegible]
10 0000 -	0 4083	1 06e 06	16	2 37e 06	23	2 94e 06	22	1 37e 06	18	3 37e 06	20	4 15e 06	15	3 38e 06	25	4 78e 06	30	5 46e 06	[illegible]

1

ENERGY SPECTRA OF ESCAPING PHOTONS
(NUMBER MEV, NORMALIZED TO ONE INCIDENT PARTICLE)

E (MEV)

100 0000	90 0000	6 30e 06	16
90 0000	80 0000	1 06e 05	10
80 0000 -	70 0000	1 45e 05	10
70 0000	60 0000	1 94e 05	7
60 0000	50 0000	2 13e 05	7
50 0000 -	40 0000	2 97e 05	6
40 0000	30 0000	3 84e 05	7
30 0000 -	20 0000	5 91e 05	4
20 0000	10 0000	1 18e 04	3
10.0000	0 0010	1 07e 03	1

ANGULAR DISTRIBUTIONS OF ESCAPING PHOTON INTENSITY
(MEV/SR, NORMALIZED TO ONE INCIDENT PARTICLE)

0 PHI(DEG)= 0 000 / 180 000

THETA (DEG)			
0 0000 -	10 0000	1 33e+00	2
10 0000 -	20 0000	1 74e 03	16
20 0000 -	30 0000	2 47e 05	33
30 0000 -	40 0000	2 00e 05	32
40 0000	50 0000	1 32e 05	27
50 0000 -	60 0000	9 58e 06	28
60 0000 -	70 0000	7 41e 06	13
70 0000 -	80 0000	4 89e 06	21
80 0000 -	90 0000	3 02e 06	20
90 0000 -	100 0000	3 07e 06	20
100 0000	110 0000	4 09e 06	25
110 0000	120 0000	4 11e 06	16
120 0000 -	130 0000	4 71e 06	11
130 0000 -	140 0000	4 43e 06	25
140.0000	150 0000	4 62e 06	20
150 0000	160 0000	4 55e 06	23
160 0000 -	170 0000	4 55e 06	18
170.0000	180 0000	4 14e 06	39

0 ENERGY SPECTRA AND ANGULAR DISTRIBUTIONS OF ESCAPING PHOTONS
AZIMUTHAL INTERVAL IS 0 00000 TO 180.00000 DEGREES
(NUMBER/(MEV·SR), NORMALIZED TO ONE PARTICLE)

0 E (MEV)	THETA= 0 000 / 10 000		10.000 / 20.000		20 000 / 30 000		30 000 / 40 000		40 000 / 50 000		50 000 / 60 000		60 000 / 70 000		70 000 / 80 000		80 000 / 90 000	
100 0000 - 90 0000	6 50e 05	16	3 53e 07	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99
90 0000 - 80 0000	1 10e 04	10	3 53e 07	99	0 00e+00	99	0.00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99
80 0000 - 70 0000	1 51e 04	10	3 53e 07	99	0 00e+00	99	0.00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0.00e+00	99	0 00e+00	99
70 0000 - 60 0000	2 02e 04	7	3 53e 07	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0.00e+00	99	0 00e+00	99
60.0000 - 50 0000	2 23e 04	7	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99
50 0000 - 40 0000	3.11e 04	6	0 00e+00	99	0.00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0.00e+00	99	0 00e+00	99
40 0000 - 30 0000	4 02e 04	7	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99
30 0000 20 0000	6 18e 04	4	3 53e 07	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99
20 0000 - 10 0000	1 23e 03	3	2 12e-06	57	0 00e+00	99	0 00e+00	99	0.00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99
10.0000 - 0.0010	9 57e 03	1	2 75e 05	12	2.18e 05	7	1 70e 05	11	1 36e 05	11	1 20e 05	9	1.26e 05	6	8 70e 06	9	7 [illegible]	11
0 INTEGRAL (/SR)	1 29e 01	1	3 14e 04	13	2 18e 04	7	1 70e 04	11	1 36e 04	11	1 20e 04	9	1 26e 04	6	8 70e-05	9	7 [illegible]	11

0 ENERGY SPECTRA AND ANGULAR DISTRIBUTIONS OF ESCAPING PHOTONS
AZIMUTHAL INTERVAL IS 0 00000 TO 180 00000 DEGREES
(NUMBER/(MEV·SR), NORMALIZED TO ONE PARTICLE)

0 E (MEV)	THETA= 90 000 / 100 000		100 000 / 110 000		110 000 / 120 000		120 000 / 130 000		130 000 / 140 000		140 000 / 150 000		150 000 / 160 000		160 000 / 170 000		170 000 / 180 000	
100 0000 90 0000	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	[illegible]	[illegible]
90.0000 - 80 0000	0.00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	0 00e+00	99	[illegible]	[illegible]

80.0000 - 70.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
70.0000 - 60.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
60.0000 - 50.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
50.0000 - 40.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
40.0000 - 30.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
30.0000 - 20.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
20.0000 - 10.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
10.0000 - 0.0010	7.33e-06	13	1.02e-05	8	1.14e-05	10	1.42e-05	10	1.25e-05	13	1.29e-05	9	1.34e-05	13	1.66e-05	16	1.68e-05	[illegible]
0 INTEGRAL (/SR)	7.33e-05	13	1.02e-04	8	1.14e-04	10	1.42e-04	10	1.25e-04	13	1.29e-04	9	1.34e-04	13	1.66e-04	16	1.68e-04	[illegible]

THE NUMBER OF DATA FOR WHICH STATISTICAL ESTIMATES HAVE BEEN PROVIDED IS 500

095200

GAAS

USER NUMBER	095200
WORKER MACHINE	Y
DATE SENT	10-Oct 1985
TIME SENT	13 03 57
XEROX UNIT	A
PAGES DATE	10 Oct 1985
PAGES TIME	13 06 14 JOB 45490 pages1

```
1 ****************************************
  *                                      *
  *     PROGRAM ITS    DECEMBER 16  1984 *
  *           VERSION 1 0                *
  *                                      *
  ****************************************
  *           A C C E P T                *
  *                                      *
  ****************************************
ONUMBER OF MATERIALS
     2
O**********************************************************
 * GAMMA RAY CROSS SECTION DATA FOR MATERIAL NUMBER   1  *
 **********************************************************
OMPAIR  NTAB  MTAX
   25     6    39     7     3     2     3     4
OENERGIES (MEV)
 1000 000000  800 000000  600 000000  500 000000  400 000000  300.000000
  200.000000  150 000000  100 000000   80 000000   60 000000   50 000000
   40.000000   30 000000   20 000000   15 000000   10 000000    8.000000
    6.000000    5 000000    4 000000    3.000000    2 000000    1.500000
    1 000000    0 800000    0 600000    0 500000    0 400000    0 300000
    0.200000    0 150000    0 100000    0 080000    0 060000    0.050000
    0.040000    0 030000    0 027940
    0 027940    0.020000    0 015000    0 010000    0 008000    0.006000
    0 004238
    0 004238    0 004000    0 003938
    0 003938    0 003730
    0 003730    0 003000    0 002144
    0 002144    0 002000    0.001500    0 001000
OTOTAL ATTENUATION COEFFICIENTS (CM2/G)
    0.072765    0 072086    0 071064    0 070308    0 069253    0.067681
    0.064989    0.062724    0 059391    0.056593    0 053592    0.051730
    0 049243    0 045587    0 040515    0.038040    0 035902    0 035012
    0 034265    0 034193    0 034702    0 036525    0 041606    0 047119
    0.058324    0 066125    0 078504    0 088619    0 105375    0 140815
    0 256863    0 459567    1 231901    2.221800    4 849174    7 973909
   14.587593   31 164482   37 392754
    6.399423   16 079271   35 586170  108 562369  199 314251  430 412449
 1051 376794
  926 192751 1076 239060 1120 238487
  848.410361  973.346916
  400.500743  709 298048 1633 529058
 1127 930930 1332.018662 2623 326525 6389 511380
ORATIO OF SCATTERING PLUS PAIR PRODUCTION TO TOTAL ATTENUATION COEFFICIENTS
    0.999991    0 999988    0 999984    0 999980    0 999975    0 999966
    0.999947    0 999926    0 999882    0 999845    0 999781    0 999726
    0 999637    0 999471    0 999084    0 998666    0 997771    0 997034
    0 995702    0 994574    0 992817    0 989768    0 983155    0.975570
    0 956872    0 938869    0 900503    0 862535    0 794654    0 663924
    0 418614    0 255285    0 105735    0 061530    0 029729    0.018604
    0 010481    0 005065    0 004250
    0 024833    0 010154    0 004670    0 001559    0 000855    0 000399
    0 000165
    0 000187    0 000161    0 000155
    0 000204    0 000178
    0 000433    0 000245    0 000107
    0 000155    0 000131    0 000067    0.000027
ORATIO OF SCATTERING TO SCATTERING PLUS PAIR PRODUCTION ATTENUATION COEFFICIENTS
    0 002922    0 003679    0 004958    0 005917    0 007578    0 010266
    0 015819    0 021566    0 033314    0 042926    0 058763    0 071528
    0 091183    0 125583    0 196442    0 261915    0 376217    0 453464
    0 567301    0 643989    0 736247    0 841514    0 945837    0 986533
    1 000000
```

```
OK SHELL IONIZATION DATA
OBINDING ENERGY (MEV), PHOTOEFFECT EFFICIENCY AND FLUORESCENT EFFICIENCY
    0.027940     0 832399     0.827839
OK X-RAY ENERGIES (MEV)
    0.024710     0.024710     0.024710     0 024710
OK X-RAY ACCUMULATED RELATIVE INTENSITIES
    1.000000     1.000000     1.000000     1.000000
OAUGER ELECTRON ENERGIES (MEV)
    0.024710     0 024710     0.024710
OAUGER ELECTRON ACCUMULATED RELATIVE INTENSITIES
    1.000000     1.000000     1.000000
O*******************************************************
 * GAMMA RAY CROSS SECTION DATA FOR MATERIAL NUMBER   2  *
 *******************************************************
OMPAIR  NTAB  MIAX
   25      9    41     2     8     3     2     2     2     2     2
OENERGIES (MEV)
 1000.000000  800 000000  600.000000  500.000000  400 000000  300.000000
  200.000000  150 000000  100.000000   80 000000   60.000000   50 000000
   40.000000   30 000000   20.000000   15.000000   10.000000    8.000000
    6.000000    5 000000    4 000000    3.000000    2.000000    1 500000
    1.000000    0 800000    0.600000    0 500000    0 400000    0.300000
    0.200000    0 150000    0.100000    0 080000    0.060000    0 050000
    0.040000    0 030000    0.020000    0 015000    0 011867
    0.011867    0 010367
    0.010367    0.010000    0.008000    0.006000    0.004000    0.003000
    0 002000    0 001530
    0.001530    0.001500    0.001359
    0.001359    0 001323
    0.001323    0 001300
    0 001300    0 001142
    0.001142    0 001115
    0.001115    0 001000
OTOTAL ATTENUATION COEFFICIENTS (CM2/G)
    0.060173    0 059621    0.058788    0 058165    0 057303    0.056005
    0.053787    0 051934    0.048963    0.046697    0.044178    0.042643
    0.040706    0 038095    0 034773    0.033158    0 031708    0.031226
    0.031146    0 031548    0.032637    0 035130    0 040841    0.046461
    0.056969    0 063728    0.073495    0.080568    0.090771    0.108617
    0.156168    0.232022    0.519524    0.897401    1.931400    3.204058
    6.011995   13 582092   42.219955   92.061788  169.049007
   88.555587  125.134417
   32.240310   35 706283   66.753770  147.467145  443.091478  955 117843
 2732.050663 5257 113182
 4921.179093 5143.463319 6436.545700
 5490.863273 5988 838578
 3846 426669 3993 258492
 3525.331716 4840.813860
 3578 786478 3983 385737
 1390.333237 1775 183143
ORATIO OF SCATTERING PLUS PAIR PRODUCTION TO TOTAL ATTENUATION COEFFICIENTS
    0.999996    0 999995    0.999994    0.999992    0 999990    0 999987
    0.999980    0.999972    0.999955    0.999941    0 999916    0 999895
    0.999862    0 999801    0 999667    0.999525    0 999223    0 998982
    0.998566    0 998229    0.997722    0 996868    0 995042    0.992921
    0.987487    0.982006    0 969600    0 956339    0 929900    0 867642
    0.694056    0 509703    0.252731    0 153559    0 075239    0.046670
    0.025634    0.011714    0 003898    0 001820    0 001002
    0.001913    0 001361
    0.005284    0 004778    0.002575    0.001174    0.000394    0.000183
    0.000064    0 000034
    0 000036    0 000034    0 000027
    0 000032    0 000029
    0.000046    0.000044
```

```
     0 000050     0 000036
     0 000049     0 000044
     0.000127     0.000099
ORATIO OF SCATTERING TO SCATTERING PLUS PAIR PRODUCTION ATTENUATION COEFFICIENTS
     0.003562     0 004484     0 006042     0 007307     0 009231     0 012506
     0.019266     0.026255     0.040730     0 052435     0 071847     0 087451
     0 111168     0 151439     0 230586     0 302629     0 428773     0 511521
     0.627310     0 701006     0.785222     0 875673     0 959669     0 990910
     1.000000
OK SHELL IONIZATION DATA
OBINDING ENERGY (MEV), PHOTOEFFECT EFFICIENCY AND FLUORESCENT EFFICIENCY
     0.011867     0 476827     0 520756
OK X-RAY ENERGIES (MEV)
     0.010690     0 010690     0 010690     0 010690
OK X-RAY ACCUMULATED RELATIVE INTENSITIES
     1.000000     1 000000     1.000000     1.000000
OAUGER ELECTRON ENERGIES (MEV)
     0.010690     0.010690     0.010690
OAUGER ELECTRON ACCUMULATED RELATIVE INTENSITIES
     1.000000     1.000000     1.000000
1*********************************************************
 *    ELECTRON CROSS SECTION DATA FROM PROGRAM DATPAC     *
 *********************************************************
ONUMBER OF SETS ON DATAPAC TAPE =    2
O*******************100.0 MEV CROSS SECTIONS FOR PHOTOCONDUCTORS                        ********************

OMATERIAL       DENSITY        DETOUR
        1  0.47800e+01  0.73100e+00
          Z               A               W
  0 15000e+02  0 30974e+02  0 21200e+00
  0.49000e+02  0.11482e+03  0 78800e+00
  NSET  ITRM  IZIP  ISGN  ISUB  INAL  ICYC  NCYC  NMAX       EMAX              EMIN              RMAX          IMAT
     1     5     0     1    40     1     1     8    64  1 0000000e+02  3 9062500e-01  2 3175160e+01     2
  DATAPREP DATA FOR DATAPAC SET    1    64    33    40   121  2 317516e+01


OMATERIAL       DENSITY        DETOUR
        2  0.53200e+01  0.39500e+00
          Z               A               W
  0.31000e+02  0 69720e+02  0 48200e+00
  0.33000e+02  0.74922e+02  0 51800e+00
  NSET  ITRM  IZIP  ISGN  ISUB  INAL  ICYC  NCYC  NMAX       EMAX              EMIN              RMAX          IMAT
     2     5     0     1    40     1     1     8    64  1 0000000e+02  3 9062500e-01  2 5400030e+01     2
  DATAPREP DATA FOR DATAPAC SET    2    64    33    40   121  2 540003e+01

O COLLISION / TOTAL DE/DX RATIOS FOR DATAPAC SET    2
O CUMULATIVE BREMSSTRAHLUNG CROSS SECTIONS FOR DATAPAC SET    2
O CUMULATIVE BREMSSTRAHLUNG ANGULAR DISTRIBUTIONS FOR DATAPAC SET    2
O LANGAUSS - EQUIPROBABLE ENDPOINTS FOR INTERPOLATION
O K X-RAY PRODUCTION FOR DATAPAC SET    2
O PHOTOELECTRON ANGULAR DISTRIBUTIONS
O PAIR ELECTRON ENERGY DIVISION DISTRIBUTION (LEAD)
1*************************
 *   BEGIN READING INPUT   *
 *************************
TITLE
   100.0 MEV KEIPPER TEST PROGRAM
***************GEOMETRY*******************************
GEOMETRY 1 0

                                                 BODY DATA
RPP 0 00 0 50 0 00 0 10 0 00 0 05
REAL DATA FOR BODY    1 IS STORED IN FPD ARRAY LOCATIONS    3 THROUGH    8
```

```
SPH 0.00 0.00 0.00 2.0
REAL DATA FOR BODY    2 IS STORED IN FPD ARRAY LOCATIONS    11 THROUGH    14
SPH 0.00 0.00 0.00 4.0
REAL DATA FOR BODY    3 IS STORED IN FPD ARRAY LOCATIONS    17 THROUGH    20
END
NUMBER OF BODIES        3

                                                            INPUT ZONE DATA
Z1 +1
Z2 +2 -1
Z3 +3 -2
END
0  COMPARISON OF GEOMETRY REQUIREMENTS VS ALLOCATIONS
LENGTH OF ARRAY CONTAINING REAL BODY DATA           / IFPD    =    20  /    1000
NUMBER OF INPUT ZONES                                / INZON   =     3  /     100
NUMBER OF CODE ZONES                                 / INUMR   =     3  /     100
LENGTH OF GEOMETRY ARRAY CONTAINING INTEGER DATA     / IIMA    =    65  /    1000
LENGTH OF ARRAY CONTAINING CODE ZONE BODY DATA       / IJTY    =     2  /      50


CODE ZONE     INPUT ZONE     ZONE DATA LOC     NO  OF BODIES
     1             1              16                1
     2             2              20                2
     3             3              28                2


OPTION 1 WAS USED IN CALCULATING VOLUMES FOR    3 INPUT ZONES
  IVOPT        MEANING
    0      - ALL VOLUMES SET TO 1.0.
    1      - READ INPUT VOLUMES
    2      - USER LOGIC TO COMPUTE VOLUMES.


          VOLUMES(CM**3)
   ZONE          1            2            3
VOLUME  2.500e-03    3.350e+01    2.679e+02
*MAT ECUT PTCZ
2
0
0
*********************SOURCE************************
ELECTRONS
ENERGY 100.0
POSITION 0.0 0.0 0.0
RADIUS 0.5
DIRECTION 0.0
CUTOFFS 0.05 0.001
*******************OUTPUT OPTIONS*******************
ELECTRON-ESCAPE
NBINE 10
PHOTON-ESCAPE
NBINE 10
ELECTRON-FLUX 1 1
NBINE 10
PHOTON-FLUX 1 1
NBINE 10
*********************OTHER OPTIONS******************
HISTORIES 1000000
0 EOF ON UNIT  5 BEGIN PROCESSING   INPUT
1*********************************************************
 *   COMPARISON OF STORAGE REQUIREMENTS VS ALLOCATIONS   *
 *********************************************************
0NUMBER OF MATERIALS ON CROSS SECTION FILE                          / IUMT    =    2  /     5
```

```
LENGTH OF ELECTRON CROSS SECTION ENERGY GRID                              / INMAX  =   64 /   64
ELECTRON ENERGY GRID LENGTH FOR SAMPLING BREMS  PHOTON ENERGY             / IMTOP  =   65 /   65
PHOTON ENERGY GRID LENGTH FOR SAMPLING BREMS  PHOTON ENERGY               / IKTOP  =   49 /   49
ELECTRON ANGLE GRID LENGTH FOR SAMPLING ELECTRON SCATTERING ANGLE         / IMMAX  =   33 /   33
PHOTON ANGLE GRID LENGTH FOR SAMPLING BREMS  PHOTON ANGLE                 / INPANG =   21 /   21
PHOTON ENERGY GRID LENGTH FOR SAMPLING BREMS  PHOTON ANGLE                / INRANG =   25 /   25
ELECTRON ENERGY GRID LENGTH FOR SAMPLING BREMS  PHOTON ANGLE              / INTANG =    9 /    9
PHOTON ENERGY GRID LENGTH FOR SAMPLING PHOTO ELECTRON DIRECTION           / INCEL  =   13 /   17
ELECTRON ANGLE GRID LENGTH FOR SAMPLING PHOTO ELECTRON DIRECTION          / INPEL  =   21 /   21
PHOTON ENERGY GRID LENGTH FOR SAMPLING PAIR ELECTRON ENERGY               / INEPS  =    9 /   17
ELECTRON ENERGY GRID LENGTH FOR SAMPLING PAIR ELECTON ENERGY              / INPPS  =   21 /   21
GAUSSIAN FUNCTION GRID FOR SAMPLING ELECTRON ENERGY LOSS STRAGGLING       / INGAS  =  100 /  100
LANDAU FUNCTION GRID FOR SAMPLING ELECTRON ENERGY LOSS STRAGGLING         / INLAN  =  500 /  500
MAXIMUM NUMBER OF TABLES OF PHOTON CROSS SECTIONS                         / INTAB  =    9 /   15
MAXIMUM LENGTH OF PHOTON CROSS SECTION TABLE                              / IMTAX  =   41 /   48
NUMBER OF ELECTRON ESCAPE ENERGY BINS                                     / IJMAX  =   10 /   50
NUMBER OF PHOTON ESCAPE ENERGY BINS                                       / IJPMAX =   10 /   50
NUMBER OF ELECTRON ESCAPE POLAR ANGLE BINS                                / IKMAX  =   18 /   36
NUMBER OF PHOTON ESCAPE POLAR ANGLE BINS                                  / IKPMAX =   18 /   36
LENGTH OF SOURCE SPECTRUM ENERGY GRID                                     / IJSPEC =    0 /   51
NUMBER OF PULSE HEIGHT ENERGY BINS                                        / IJSMAX =    0 /   53
NUMBER OF ELECTRON FLUX ENERGY BINS                                       / IJEMAX =   10 /   50
NUMBER OF PHOTON FLUX ENERGY BINS                                         / IJEMXP =   10 /   50
NUMBER OF ELECTRON FLUX ZONES                                             / INLE   =    1 /   10
NUMBER OF PHOTON FLUX ZONES                                               / INLEP  =    1 /   10
NUMBER OF PROBLEM ZONES                                                   / INZON  =    3 /  100
SIZE OF DOUBLY DIFFERENTIAL BREMS DISTRIBUTION                            / NCHANG = 4725 / 4725
SIZE OF SINGLY DIFFERENTIAL BREMS DISTRIBUTION                            / NBDIS  = 3185 / 3185
SIZE OF GOUDSMIT-SAUNDERSON ANGULAR DISTRIBUTION                          / NGG    = 2112 / 2112
NO  OF ELECTRON ESCAPE AZIMUTHAL ANGLE BINS                               / IKMAZ  =    1 /    1
NO. OF PHOTON ESCAPE AZIMUTHAL ANGLE BINS                                 / IKPMAZ =    1 /    1
O************* GLOBAL ELECTRON CUTOFF ENERGY BELOW ELECTRON ENERGY LIST.  CUTOFF ENERGY HAS BEEN CHANGED TO  0.408302e+00
1*********************************
 *   GEOMETRY DEPENDENT INPUT    *
 *********************************
O                        ELECTRON     PHOTON
  INPUT                   CUTOFF    STRETCHING
  ZONE  MATERIAL          (MEV)       FACTOR
    1       2           4 083e 01    1 000e+00
    2       0           4 083e 01    1 000e+00
    3       0           4 083e 01    1 000e+00
1*************************
 *   SOURCE INFORMATION  *
 *************************
OSOURCE ELECTRONS
OTHE MAXIMUM SOURCE ENERGY IS      100 00000 MEV
OTHE GLOBAL ELECTRON CUTOFF ENERGY IS       0 40830 MEV
OTHE PHOTON CUTOFF ENERGY IS       0 00100 MEV
OCOORDINATES OF THE POINT SOURCE OR OF THE CENTER OF THE BEAM (DISK) SOURCE ARE
     X =  0 00000e+00 CM              Y =  0 00000e+00 CM              Z =  0 00000e+00 CM
OTHE RADIUS OF THE BEAM (DISK) SOURCE IS =    5 0000e 01 CM
OREFERENCE DIRECTION FOR ANGULAR DISTRIBUTION IS DEFINED BY
     THETA =    0.0000 DEGREES            PHI =    0 0000 DEGREES
OMONODIRECTIONAL SOURCE IN REFERENCE DIRECTION
OTHE STANDARD ERROR ESTIMATES ARE BASED ON     10 BATCHES OF   100000 HISTORIES EACH
1*********************
 *   OUTPUT OPTIONS  *
 *********************
OELECTRON ESCAPE ENERGY CLASSIFICATIONS (MEV)
     90 00000     80 00000     70 00000     60 00000     50 00000     40 00000
     30 00000     20 00000     10 00000      0 40830
OELECTRON ESCAPE POLAR ANGLE CLASSIFICATIONS (DEGREES)
     10 00000     20 00000     30 00000     40 00000     50 00000     60 00000
     70 00000     80 00000     90 00000    100 00000    110 00000    120 00000
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   130 00000    140 00000    150 00000    160.00000    170 00000    180 00000
OELECTRON-ESCAPE AZIMUTH ANGLE CLASSIFICATIONS (DEGREES)
   180 00000
OPHOTON-ESCAPE ENERGY CLASSIFICATIONS (MEV)
    90 00000     80 00000     70 00000     60 00000     50 00000     40 00000
    30 00000     20.00000     10 00000      0 00100
OPHOTON-ESCAPE POLAR ANGLE CLASSIFICATIONS (DEGREES)
    10 00000     20 00000     30 00000     40 00000     50 00000     60 00000
    70 00000     80 00000     90 00000    100 00000    110 00000    120 00000
   130.00000    140 00000    150.00000    160 00000    170 00000    180 00000
OPHOTON-ESCAPE AZIMUTH ANGLE CLASSIFICATIONS (DEGREES)
   180.00000
OELECTRON-FLUX ENERGY CLASSIFICATIONS (MEV)
    90.00000     80 00000     70 00000     60 00000     50 00000     40 00000
    30.00000     20 00000     10.00000      0 40830
OPHOTON-FLUX ENERGY CLASSIFICATIONS (MEV)
    90 00000     80 00000     70 00000     60 00000     50 00000     40 00000
    30.00000     20 00000     10.00000      0 00100
1*********************
 *  PHYSICAL OPTIONS  *
 *********************
OELECTRON COLLISION AND RADIATION ENERGY LOSS STRAGGLING
OKNOCK ON ELECTRON PRODUCTION
ONO COUPLED INELASTIC SCATTERING DEFLECTIONS
OBREMSSTRAHLUNG AND CHARACTERISTIC X-RAY QUANTA FOLLOWED
OBREMSSTRAHLUNG INTRINSIC ANGLE OF EMISSION FROM TABULATED DISTRIBUTION
OPHOTON-PRODUCED ELECTRONS FOLLOWED
O        MATERIAL NO   1
 ELECTRON RANGE AT MAXIMUM SOURCE ENERGY IS       0.23175e+02 (G/CM**2)
 K X-RAY QUANTA FOLLOWED
 ELECTRON IMPACT IONIZATION SAMPLED
O        MATERIAL NO   2
 ELECTRON RANGE AT MAXIMUM SOURCE ENERGY IS       0.25400e+02 (G/CM**2)
 K X-RAY QUANTA FOLLOWED
 ELECTRON IMPACT IONIZATION SAMPLED
OANNIHILATION QUANTA FOLLOWED
1***************************************************************************
 *                                                                         *
 * .. 100 O MEV KEIPPER TEST PROGRAM                                       *
 *                                                                         *
 ***************************************************************************
OTHE PROBLEM IS  100  PERCENT COMPLETE   TIME TO FINISH IS        0.000 SECONDS  AVERAGE TIME PER BATCH IS       16.886
OAVERAGE SOURCE ENERGY = 1.0000e+02  O MEV
OTHE INITIAL RANDOM NUMBER OF THIS RUN IS 00000000000000000000
 THE INITIAL RANDOM NUMBER OF THE CURRENT BATCH IS 000012112447407O6165
 THE  FINAL  RANDOM NUMBER OF THE CURRENT BATCH IS 000001140272434166 55
O     ------------------------------------ HISTORIES -----------------------------      REJ      REJ      -- STEPS
     PRIM      SEC    KNOCK      P E     PAIR     COM    AUGER     BREM     RAD     XRAY     LAND     PEAL      PRIM      SEC
  1000000     2931     2869        1       48      13        0    11854   11880     7554       14        0   1063547    11209
O                                 ENERGY (MEV)      AVE ENERGY (MEV)      NUMBER/PRIMARY      NUMBER GENERATED
 FIRST KNOCK (ABOVE TCUT)         5 5666e-03         1 9587e+00          2.8420e 03              2842
 TOTAL KNOCK (ABOVE TCUT)         5 5854e-03         1.9468e+00          2.8690e 03              2869
 PHOTO-ELECTRON                   8 5095e 05         1.1188e 02          7.6060e 03              7606
 PAIR                             6 5704e 04         1 2635e+01          5 2000e 05                52
 COMPTON                          3 5865e-05         4.3211e 01          8 3000e 05                83
 AUGER                            7 3921e 05         1 0690e 02          6 9150e 03              6915
 FIRST BREMSSTRAHLUNG             1 2147e 01         1.0511e+01          1.1556e 02             11556
 TOTAL BREMSSTRAHLUNG             1 2153e 01         1 0230e+01          1 1880e 02             11880
 K X RAY(P IONIZATION)            1 6035e 07         1 0690e 02          1 5000e 05                15
 K X-RAY(E IONIZATION)            8 0592e 05         1 0690e 02          7 5390e 03              7539
 ANNIHILATION QUANTA              3 0659e 06         5 1098e 01          6.0000e 06                 6

1UNSCATTERED PRIMARY PHOTONS - NUMBER AND ENERGY FRACTIONS
 O 00e+00 99 0 00e+00 99
```

```
***UNSCATTERED PRIMARY PHOTONS ARE EXCLUDED FROM ALL SUBSEQUENT PHOTON ESCAPE TALLIES***
ONUMBER ESCAPE FRACTIONS -- KNOCK ON AND PHOTON GENERATED ELECTRONS, ANNIHILATION RADIATION, K X RAYS (MATERIAL NO. )
0                                                TOTAL ESCAPE
        KNOCK           P SEC          ANNIH     K-X RAY(1)    K-X RAY(2)    K-X RAY(3)    K-X RAY(4)    K-X RAY(5)
   1.63e-03  2    5.50e-05 12    6.00e-06 51    0.000e+00 99    1.67e-04  7

0                                        NUMBER AND ENERGY ESCAPE FRACTIONS
0                                                TOTAL ESCAPE
0                          ------ ELECTRON ------                    ------ PHOTON ------
                     NUMBER        ENERGY        COUNTS       NUMBER        ENERGY        COUNTS

                  1.00e+00  0  9.99e-01  0     1001687   1.18e-02  1  1.21e-03  2      11782
1                                       ENERGY AND CHARGE DEPOSITION
                                     (NORMALIZED TO ONE INCIDENT PARTICLE)
                                ENERGY(MEV)                                                CHARGE(ELECTRONS)
 ZONE MAT          PRIM             KNOCK           G SEC            TOTAL              PRIM           KNOCK           G SEC            TOTAL

    1    2      2.454e-02  1   4.632e-03  4   1.855e-05 11   1.993e-02  1      0.000e+00 99   1.916e-03  2   7.700e-05 16   1.993e-03  2
    2    0      0.000e+00 99   0.000e+00 99   0.000e+00 99   0.000e+00 99      0.000e+00 99   0.000e+00 99   0.000e+00 99   0.000e+00 99
    3    0      0.000e+00 99   0.000e+00 99   0.000e+00 99   0.000e+00 99      0.000e+00 99   0.000e+00 99   0.000e+00 99   0.000e+00 99
0   TOTAL       2.454e-02  1   4.632e-03  4   1.855e-05 11   1.993e-02  1      0.000e+00 99   1.916e-03  2  -7.700e-05 16  -1.993e-03  2
0 THE ENERGY CONSERVATION FRACTION IS        0.9999990099095e+00  0
1FLUX CALCULATION - ELECTRONS LEFT AT FLUX CUTOFF ENERGY (NUMBER, NORMALIZED TO ONE INCIDENT PARTICLE)
        1
 1.22e-03  2
1                                          ELECTRON FLUX DISTRIBUTION
                               (TRACK-LENGTH/VOLUME-MEV, NORMALIZED TO ONE INCIDENT PARTICLE)
OE(MEV)   ZONE=      1

   90.0000    1.24e-01   1
   80.0000    1.19e-03   2
   70.0000    5.94e-04   4
   60.0000    3.81e-04   6
   50.0000    2.84e-04   5
   40.0000    1.81e-04   6
   30.0000    1.86e-04  10
   20.0000    1.58e-04   6
   10.0000    1.67e-04   7
    0.4083    3.26e-03   2
1                                          PHOTON FLUX DISTRIBUTION
                               (TRACK LENGTH/VOLUME MEV, NORMALIZED TO ONE INCIDENT PARTICLE)
OE(MEV)   ZONE=      1

   90.0000    6.78e-05  16
   80.0000    1.05e-04  10
   70.0000    1.42e-04   7
   60.0000    1.90e-04   8
   50.0000    1.98e-04   7
   40.0000    2.71e-04   6
   30.0000    3.53e-04   8
   20.0000    5.59e-04   5
   10.0000    1.13e-03   3
    0.0010    9.21e-03   1

1                                   ENERGY SPECTRA OF ESCAPING ELECTRONS
                               (NUMBER/MEV, NORMALIZED TO ONE INCIDENT PARTICLE)
        E (MEV)
  100.0000 -   90.0000    9.97e-02   0
   90.0000 -   80.0000    1.13e-04   3
   80.0000 -   70.0000    5.61e-05   4
   70.0000 -   60.0000    3.60e-05   5
   60.0000 -   50.0000    2.83e-05   5
   50.0000 -   40.0000    2.02e-05   6
   40.0000 -   30.0000    1.96e-05   7
```

30.0000 -	20.0000	1.74e-05	3
20.0000 -	10.0000	1.89e-05	6
10.0000 -	0.4083	1.72e-04	2

ANGULAR DISTRIBUTIONS OF ESCAPING ELECTRONS
(NUMBER/SR, NORMALIZED TO ONE INCIDENT PARTICLE)

0

THETA (DEG)		PHI(DEG)= 0.000 180.000	
0.0000 -	10.0000	1.05e+01	0
10.0000 -	20.0000	7.66e-04	6
20.0000 -	30.0000	5.12e-04	8
30.0000 -	40.0000	4.06e-04	6
40.0000 -	50.0000	3.01e-04	6
50.0000 -	60.0000	2.08e-04	7
60.0000 -	70.0000	1.21e-04	12
70.0000 -	80.0000	8.32e-05	11
80.0000 -	90.0000	4.58e-05	16
90.0000 -	100.0000	3.12e-05	11
100.0000 -	110.0000	3.50e-05	14
110.0000 -	120.0000	2.72e-05	23
120.0000 -	130.0000	4.12e-05	15
130.0000 -	140.0000	3.74e-05	15
140.0000 -	150.0000	3.18e-05	24
150.0000 -	160.0000	3.46e-05	25
160.0000 -	170.0000	3.17e-05	31
170.0000 -	180.0000	3.14e-05	51

0

ENERGY SPECTRA AND ANGULAR DISTRIBUTIONS OF ESCAPING ELECTRONS
AZIMUTHAL INTERVAL IS 0.00000 TO 180.00000 DEGREES
(NUMBER/(MEV*SR), NORMALIZED TO ONE PARTICLE)

0

E (MEV)		THETA= 0.000 10.000		10.000 20.000		20.000 30.000		30.000 40.000		40.000 50.000		50.000 60.000		60.000 70.000		70.000 80.000		80.000 90.000	
100.0000 -	90.0000	1.04e+00	0	3.53e-07	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
90.0000 -	80.0000	1.18e-03	3	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
80.0000 -	70.0000	5.87e-04	4	0.00e+00	99	2.16e-07	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
70.0000 -	60.0000	3.77e-04	5	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
60.0000 -	50.0000	2.96e-04	5	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
50.0000 -	40.0000	2.12e-04	6	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
40.0000 -	30.0000	2.02e-04	7	1.06e-06	51	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
30.0000 -	20.0000	1.66e-04	4	5.64e-06	21	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
20.0000 -	10.0000	1.45e-04	9	1.45e-05	16	1.73e-06	49	1.59e-07	99	1.29e-07	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
10.0000 -	0.4083	1.37e-04	8	5.74e-05	7	5.14e-05	7	4.22e-05	6	3.12e-05	5	2.17e-05	7	1.26e-05	12	8.67e-06	11	4.78e-06	1

0

ENERGY SPECTRA AND ANGULAR DISTRIBUTIONS OF ESCAPING ELECTRONS
AZIMUTHAL INTERVAL IS 0.00000 TO 180.00000 DEGREES
(NUMBER/(MEV*SR), NORMALIZED TO ONE PARTICLE)

0

E (MEV)		THETA= 90.000 100.000		100.000 110.000		110.000 120.000		120.000 130.000		130.000 140.000		140.000 150.000		150.000 160.000		160.000 170.000		170.000 180.000	
100.0000	90.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
90.0000 -	80.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
80.0000 -	70.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
70.0000	60.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
60.0000	50.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
50.0000 -	40.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
40.0000 -	30.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
30.0000 -	20.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	9
20.0000	10.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	[illegible]
10.0000 -	0.4083	3.25e-06	11	3.65e-06	14	2.84e-06	21	4.30e-06	15	3.90e-06	15	3.32e-06	24	3.60e-06	25	3.31e-06	31	3.28e-06	[illegible]

1

ENERGY SPECTRA OF ESCAPING PHOTONS
(NUMBER/MEV, NORMALIZED TO ONE INCIDENT PARTICLE)

E (MEV)			
100 0000 -	90 0000	6 60e 06	10
90 0000 -	80 0000	1 11e 05	10
80 0000 -	70 0000	1 41e 05	7
70 0000 -	60 0000	1 81e 05	7
60 0000 -	50 0000	1 96e 05	7
50 0000 -	40 0000	2 69e 05	5
40 0000	30 0000	3 63e 05	6
30 0000	20 0000	5 55e 05	4
20 0000 -	10 0000	1 11e 04	2
10 0000	0 0010	8 79e 03	1

ANGULAR DISTRIBUTIONS OF ESCAPING PHOTON INTENSITY
(MEV/SR, NORMALIZED TO ONE INCIDENT PARTICLE)

0

THETA (DEG)	PHI(DEG):	0 000 180 000	
0 0000 -	10 0000	1 26e+00	2
10 0000 -	20 0000	8 77e 04	59
20 0000 -	30 0000	1 41e 05	28
30 0000 -	40 0000	1 63e 05	31
40 0000 -	50 0000	8 67e 06	29
50 0000 -	60 0000	4 85e 06	24
60 0000 -	70 0000	2 64e 06	32
70 0000 -	80 0000	1 95e 06	37
80 0000	90 0000	2 58e 06	44
90 0000	100 0000	4 13e 06	27
100 0000	110 0000	2 15e 06	65
110 0000	120 0000	1 90e 06	49
120 0000 -	130 0000	1 12e 06	29
130 0000 -	140 0000	1 88e 06	35
140 0000	150 0000	4 18e 07	48
150 0000 -	160 0000	5 67e 07	48
160 0000	170 0000	2 65e 06	69
170 0000	180 0000	1 12e 07	99

0

ENERGY SPECTRA AND ANGULAR DISTRIBUTIONS OF ESCAPING PHOTONS
AZIMUTHAL INTERVAL IS 0 00000 TO 180 00000 DEGREES
(NUMBER/(MEV*SR), NORMALIZED TO ONE PARTICLE)

0

E (MEV)	THETA	0 000 10.000	10 000 20.000	20 000 30 000	30 000 40 000	40 000 50.000	50 000 60 000	60 000 70.000	70.000 80.000	80 000 90 000
100 0000 -	90 0000	6 91e 05 10	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0.00e+00 99	0 00e+00 99
90 0000 -	80 0000	1 15e 04 9	3 53e-07 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0.00e+00 99	0 00e+00 99
80 0000 -	70 0000	1.48e 04 7	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99
70 0000 -	60 0000	1 90e 04 7	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0.00e+00 99	0 00e+00 99
60 0000 -	50 0000	2 05e 04 7	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0.00e+00 99	0 00e+00 99
50 0000 -	40 0000	2 82e 04 5	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99
40 0000	30.0000	3 80e 04 6	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0.00e+00 99	0 00e+00 99	0 00e+00 99
30 0000 -	20 0000	5 79e 04 4	7 06e 07 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0.00e+00 99	0 00e+00 99
20 0000	10 0000	1 16e 03 2	1 41e 06 41	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0.00e+00 99	0 00e+00 99
10 0000	0 0010	8 81e 03 1	1 73e 05 14	3 67e 06 26	6 05e 06 18	4 26e 06 18	2 45e 06 16	2.72e 06 18	1.99e-06 19	1 74e 06 11
0 INTEGRAL (/SR)		1 20e 01 1	1 98e 04 16	3 67e 05 26	6 05e 05 18	4 26e 05 18	2 45e 05 16	2 72e 05 18	1.99e-05 19	1 74e 05 11

0

ENERGY SPECTRA AND ANGULAR DISTRIBUTIONS OF ESCAPING PHOTONS
AZIMUTHAL INTERVAL IS 0 00000 TO 180 00000 DEGREES
(NUMBER/(MEV*SR) NORMALIZED TO ONE PARTICLE)

0

E (MEV)	THETA	90 000 100 000	100 000 110 000	110 000 120 000	120 000 130 000	130 000 140 000	140 000 150 000	150 000 160 000	160 000 170 000	170 000 180 000
100 0000 -	90 0000	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99
90 0000 -	80.0000	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99	0 00e+00 99

80.0000	70.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
70.0000	60.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
60.0000	50.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
50.0000	40.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
40.0000	30.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
30.0000	20.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
20.0000	10.0000	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99	0.00e+00	99
10.0000	0.0010	1.74e-06	21	1.32e-06	22	2.02e-06	25	2.90e-06	20	2.97e-06	22	2.39e-06	27	2.16e-06	33	2.82e-06	31	1.05e-06	99
0	INTEGRAL (/SR)	1.74e-05	21	1.32e-05	22	2.01e-05	25	2.90e-05	20	2.97e-05	22	2.39e-05	27	2.16e-05	33	2.82e-05	31	1.05e-05	99

THE NUMBER OF DATA FOR WHICH STATISTICAL ESTIMATES HAVE BEEN PROVIDED IS 500

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